OXY-ACETYLENE
and
ARC WELDING

By

STUART PLUMLEY

A COURSE
OF INSTRUCTION

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Oxy-Acetylene and Arc Welding

A Course of Instruction

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STUART PLUMLEY

THIRD EDITION

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DERECHOS DE PROPIEDAD LITERARIA
RESERVADOS MEXICO - 1930, 1931

Foreword

THE purpose of this book is to provide a course of instruction in oxy-acetylene welding and cutting which will enable students and others, desiring to learn to weld, to begin with the simplest and most elementary work and progressively study and practice the process until they are skilled in welding and cutting. The book is so arranged that accompanying each lesson is a job sheet, describing the specific work which the student is expected to do as practice work with the torch. The theoretical as well as the practical part of the process is thus progressively learned.

In the first four lessons, welding and cutting apparatus is discussed, as well as the gases, oxygen and acetylene, which produce the intense heat of the oxy-acetylene flame. In these lessons, therefor, the student is given the information which he should have about welding and cutting apparatus at the beginning of the course. It is believed that a knowledge of the gases, which are used in this process, and the equipment enabling their use, is an essential part of his education as a welder.

The text of the remainder of the lessons is confined to the process of welding and cutting, and the methods by which the process is made useful, both for repairs and production work. The one exception is Lesson No. 13, the subject of which is the Business Side of Welding, written particularly to assist the welding shop owner to systematize his shop so that it will be profitable to him.

The course may be used as a text book for high schools and colleges and for the many welding schools which are being established throughout the country. It may also be used by welding shop owners, foremen of industrial plants, and welders, to increase their knowledge of welding. The course has been written primarily to enable men who know nothing of welding to teach themselves this valuable process and to make better welders of the many good men who are now connected with the industry.

Every man studying this course should remember that welding is an art. It is not merely a trade, requiring only skilful manipulation of the hands, but a highly specialized process, demanding an excellent knowledge of the action of metals when heat is applied to them and some knowledge of most of the mechanical processes in common use.

There should be no alarm felt by the student that the subject is too difficult for him to learn. As a matter of fact, welding is not difficult. It is a relatively easy process, providing a man is willing to spend the time required in actual practice work and to study the theory and the principles used until he thoroughly understands their significance. Faithful application to this course of lessons will enable any man having a mechanical sense to thoroughly master this wonderful process.

The author desires to express his appreciation of the assistance rendered by his many friends and associates in the preparation of this book.

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The Author's Experience

STUART PLUMLEY, the author of this course of instruction, is a man fifty-nine years of age who for thirty years has been actively connected with the oxy-acetylene industry. His experience has been very broad and fortune has placed him in many positions where he has had unusual opportunities to study welding and the process in general to excellent advantage.

He graduated from school at Scranton, Pa., in 1898 and for the next ten years was an active civil engineer in mining, construction, railroad and sanitary engineering. Six years of this period were spent as an assistant civil engineer during the construction of the Lackawanna Steel Plant at Buffalo, New York.

On November, 14, 1906, he surveyed the property and located the corner stakes for the first commercial oxygen plant in the United States manufacturing oxygen by the liquid air process. This was the first plant of the Linde Air Products Company, located at Chandler, Manton and Grote Streets, Buffalo, New York.

In 1908 he saw and operated his first oxy-acetylene torch and the process interested him so much that in 1909 he became actively connected with the industry to which he has devoted his life since that time.

He has been located in a number of different cities and has traveled all over the United States while in the employ of the largest oxygen and apparatus producing corporations.

During the war, while chief engineer of the Davis-Bournonville Company, he was also director of the Davis - Bournonville Institute, established at the Jersey City plant of that company in 1917. This institution taught over two thousand soldiers and sailors to weld.

It has been this broad experience and his familiarity with welding and welding and cutting equipment which have enabled him to produce so successful a course of instruction.

The author's experience in detail is given as follows:

STUART PLUMLEY

1898-1900	Mining Engineering Department, Pennsylvania Coal Co. and Lackawanna Iron and Steel Co., Scranton, Pa.
1900-1906	Assistant Civil Engineer, Lackawanna Steel Co., Buffalo, N. Y.
1906-1909	General Civil Engineering Practice, Buffalo, N. Y.
1909-1911	Western Sales Manager, Linde Air Products Co., East Chicago, Ind.
1911-1914	Engineer, Linde Air Products Co. and Oxweld Acetylene Co., Chicago, Ill.
1914-1916	Chief Engineer, Superior Oxygen Co., Pittsburgh, Pa.
1916-1917	District Manager, Davis-Bournonville Co., Boston, Mass.
1917-1920	Chief Engineer, Davis-Bournonville Co., Jersey City, N. J.
1920-1922	District Manager, Davis-Bournonville Co., Chicago, Ill.
1922-1923	Engineer, Air Reduction Sales Co., Chicago, Ill.
1923-1927	Managing Editor, Acetylene Journal Publishing Co., Chicago, Ill.
1927-1928	Secretary and Treasurer, Gas Products Association, Chicago, Ill.
1928-1934	Chief Engineer, Smith Welding Equipment Corporation, Minneapolis, Minn.
1934 to present.	Editor and Consulting Engineer.

Preface to Second Edition

THE first edition of this book has been sold very rapidly, indicating that there is a wide demand for a course of instruction of this kind. The book was originally written, because of the belief that there are many thousand men in the United States and other English speaking countries who want to learn to weld, or if already welders, to learn more about the oxy-acetylene process. The rapid sale of the first edition has proved that this belief is true, and that the book is of real assistance to those desiring knowledge of oxy-acetylene welding.

As each edition of the book is published, additional material, data, tables and other valuable information concerning the process and its use will be included, so that the book will be kept up to date as the process develops and advances. Careful consideration of the location of this additional material in the book indicates that the convenience of the instructor and the mechanical requirements of publication will be better served if the book is published in two parts; part one being the original contents of the first edition in lessons, written as a course of instruction, and part two being the material added to the book with each edition and divided into chapters rather than lessons.

This will not interfere with the length of the original course of instruction, divided into twenty lessons, nor will it extend each lesson, which is not thought desirable. The additional material published in this manner will be included in the general index, so that ready reference may be made to it.

It is hoped that the second edition will be as popular and as greatly in demand as the first edition, which is now nearly exhausted.

STUART PLUMLEY.

October 4, 1931.

Preface to Third Edition

SINCE the publication of the Second Edition of this book the application of welding and cutting has continued to develop and progress in many fields of manufacture, construction and repair. In fact, it is the more extended use of the process and the greater reliance of engineers upon it which make the progress of the last decade especially outstanding.

Oxy-acetylene cutting and electric welding, combined with stronger steels, have made the new light weight Diesel engine trains possible. The construction of machinery of oxy-acetylene cut and electric welded steel plates, castings and forgings has been greatly extended. Steel containers and vessels, especially in the petroleum industry, are being welded to withstand far greater pressures than ever before. Corrosion resistant metals are being welded wherever required. Buildings, bridges and boats are being welded in constantly increasing numbers.

Perhaps the greatest progress has been made in the more extended recognition which has been given welding by governmental, insurance and other authorities and the increased reliance which has been placed upon welded joints. This progress has been the result of the rules, codes, regulations and standards in which the engineering societies and the welding industry have co-operated.

Of increasing importance in recent years has been the fact that many welders are becoming "combination welders," that is those able to weld with either the torch or the arc. This involves greater skill and an ability to adapt such skill to either process. Because of the increased interest of welders in arc welding as well as oxy-acetylene welding, it has been thought desirable to include a chapter giving fundamentals and elementary practice work in arc welding. After having mastered the oxy-acetylene process as set forth in the first part of the book the student will be well prepared to begin a study of the very important subject of arc welding.

Another change from former editions is the elimination of the chapters in Part 2 which formerly gave the details of the State Boiler Laws, the Boiler Code and the Rules of the Underwriters' Laboratories, and the substitution therefor of a single chapter outlining as many as possible of the various rules and codes which govern welding. With the information in this chapter the welder may obtain from its original source the latest edition of any code which he requires.

It is hoped that this rearrangement and additional material will make this book even more valuable and popular than its previous editions.

STUART PLUMLEY.

November 15, 1939.

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Part I

Lesson No. 1

Setting Up the Equipment

IN THIS first lesson on oxy-acetylene welding and cutting equipment, it is proposed to give the student the preliminary information about the equipment and the gases which he should have at the very beginning of his study of the process. Job Sheet No. 1 gives him full details with reference to the setting up of equipment and the first job which he must undertake, namely, the application of the torch flame to pieces of steel plate.

It may be that instead of the two cylinders described in Job Sheet No. 1 the operator will find that an acetylene generator has been installed and the gas led into the welding room by a pipe line at the end of which is a pressure regulator arranged to reduce and control the pressure within the pipe line from the generator. In this event the pipe line is used as a source of acetylene supply instead of the acetylene cylinder described in Job Sheet No. 1. There is no difference in the procedure except that the acetylene regulator attached to the pipe on the wall takes the place of the acetylene regulator attached to the acetylene cylinder. Chart No. 2 shows this arrangement in detail.

Before proceeding with a description of acetylene generators, however, we will confine our remarks entirely to the cylinder equipment. The oxygen cylinder is a seamless, drawn steel bottle with walls about ½ inch in thickness and considerably heavier at the top and bottom. It contains approximately 220 cu. ft. of oxygen when full and has been charged to a pressure of 2000 pounds per square inch. This pressure is, of course, much too high to be delivered to the torch and, therefore, a pressure regulator or reducing valve is attached to the cylinder which reduces the pressure to a suitable working pressure at the torch, depending upon the size of the tip in use.

The oxygen in the oxygen cylinder is a gas compressed until it is confined in the space within the cylinder. This space within the oxygen cylinder amounts to only a little more than 1½ cubic feet and it will be readily appreciated how much the oxygen must be compressed to confine 220 cubic feet within this small area. All oxygen cylinders are manufactured and tested to comply with the rules of the Interstate Commerce Commission. It is obvious that they should be handled with care. They should never be dropped or permitted to strike each other violently, and they should not be dropped from a platform to the ground, or from the floor of a truck to the ground. In a large industrial plant cylinders should not be lifted with a crane unless they are first placed in and securely fastened to a carrier built for the purpose. They should never be lifted by a magnet attached to a crane.

Oxygen itself is not inflammable, but it supports combustion very actively, much more so than air. Oil or grease when brought into contact with oxygen becomes very inflammable and in some cases even explosive. For this reason oxygen cylinders should never be placed under line shafts where oil is apt to drip upon the valve, nor should oil ever be used on the cylinder valve, or for that matter on any other part of welding or cutting equipment, except upon acetylene generators.

Sparks or flames should not be permitted to come in contact with oxygen cylinders under any circumstances. Cylinders should never be used to support a plate or casting which is being either welded or cut. The torch might slip or the flame come in contact with the cylinder with disastrous results. Oxygen, like other gases, expands as it becomes heated and if the cylinder is placed near a hot furnace or forge it may become too warm and the pressure will increase until the safety disc on the cylinder valve bursts and permits the oxygen to escape.

Acetylene on the other hand is an entirely different gas from oxygen. It has peculiar characteristics which necessitate different treatment when it is compressed into cylinders. Because of these peculiar characteristics, which will be explained later, the acetylene cylinder is completely filled with a porous filler like a sponge made of asbestos, corn pith, charcoal and other materials, depending upon the manufacturer of the tank. This filler or porous material is in turn completely filled with a liquid called acetone which has the peculiar property of dissolving acetylene. When acetylene is compressed into the cylinder thus filled with a porous filler and acetone, the acetylene is dissolved in the acetone and under these conditions is perfectly safe for shipment and for use. If it were compressed in an ordinary tank to a pressure of more than fifteen pounds per square inch it would not be safe. The pressure within an acetylene cylinder is usually about 250 pounds. Some makes of cylinders are charged to a lower pressure than this, even when full. The pressure does not determine when the cylinder is full. Acetylene is always sold by weight and the number of cubic feet within the cylinder is determined by the weight of the gas contained within it.

The pressure within an acetylene cylinder is too great for use at the torch and for this reason an acetylene regulator is attached to the cylinder outlet valve to reduce the pressure so that the gas can be utilized to advantage. Both oxygen and acetylene regulators are very carefully designed and constructed to meet the severe service imposed upon them in reducing high pressure gases to lower pressures accurately and without leakage. If dirt or grit is allowed to enter the regulators it will seriously interfere with their operation and cause them to leak at the seat. The gauges are delicately constructed mechanisms and cannot give accurate readings unless care is taken of them. When properly cared for regulators will last for a long time and give excellent service. If they are not properly treated, however, they will give good service for only a short time and will be constantly in need of repairs.

Right at the beginning of his experience in connection with welding and cutting equipment, the operator should learn to take good care of his apparatus. The torch is a simpler piece of mechanism than the regulators, but even so, it must be properly cared for if service is to be expected. The mixing chamber in the brass section must be free from dirt. The seat of this brass mixing section where it enters the torch handle must not be nicked or scored and the threads must be protected. A protecting cap is furnished with tips to protect this thread and seat so that when they are put in a tool box or laid away where stored the seat and threads will not be injured. The port or hole through the copper section of the tip must be kept free from dirt, oxide or slag or the tip will not work properly. This is done by cleaning this port occasionally with a drill to fit the port. Tip cleaners made of proper size drills for the various tips are furnished with torches so that cleaning can be done without injury to the tip. As all of the ports through a torch bear a definite relation to each other, it is essential that the diameter of the tip port should not be enlarged or changed. Reaming out or enlarging the hole in the tip is bad practice and can only result in permanent injury to the torch.

We will pass on from the equipment to the flame produced by the welding torch and describe why this flame enables the operator to melt and control the fusion of metals of almost all kinds. This small, very hot flame is the result of the complete combustion of pure oxygen and pure acetylene. It requires 2½ parts of oxygen to consume completely one part of acetylene. It is not necessary, however, to supply all of this oxygen through the torch because a portion of the oxygen is derived from the air surrounding the flame. The torch, therefore, is designed to supply one part of oxygen to every part of acetylene which passes through it, and the flame obtains 1½ parts of oxygen from the air surrounding it to complete the combustion. Oxygen, as has been stated before, is the active supporter of combustion. Air supports combustion because of the oxygen which it contains. The oxygen content of air is only about one-fifth of the total volume; the nitrogen content, about four-fifths, is absolutely inert. Air, therefore, is greatly retarded in supporting combustion by its nitrogen content.

The element in coal which burns is its carbon content, but combined with this carbon is a considerable proportion of impurities which will not burn. In a forge fire which is ordinarily used by the blacksmith, coal and a forced draft of air are used to produce heat. Coal is impure as stated above and air contains about four-fifths, in volume, of an inert gas which will not support combustion. A coal-air fire is, therefore, not a particularly efficient means to develop a high degree of heat and the result is a much lower temperature, probably not exceeding 2,500 degrees Fahrenheit. The blacksmith in using the forge fire therefore can not do more than make a blacksmith's weld between pieces of iron and steel. He can not raise the temperature of the steel to the fusion or melting point and if he does raise the temperature by any other means, he is unable to control the metal as it can be controlled with the oxy-acetylene torch.

Acetylene is essentially pure gas carbon. It contains approximately 93% of carbon and about 7% of hydrogen. Therefore, in acetylene we have a very pure fuel which in the presence of oxygen can be completely consumed without waste of any kind. This alone, however, would not explain the very high temperature of the oxy-acetylene flame. Acetylene has some peculiar characteristics, one of which is given to it by the carbide from which it is made. Carbide absorbs heat during its formation and this chemically stored up heat is given off by the acetylene when combustion takes place.

A gas having this characteristic is known as an endothermic gas and acetylene is one of the few endothermic gases known. This peculiar quality enables acetylene and oxygen to produce one of the hottest and most highly concentrated gas flames known. The temperature of this flame is about 6,300 degrees Fahrenheit although some authorities declare that it does not exceed 5,800 degrees. Other gases and oxygen will produce hot flames having temperatures approximating

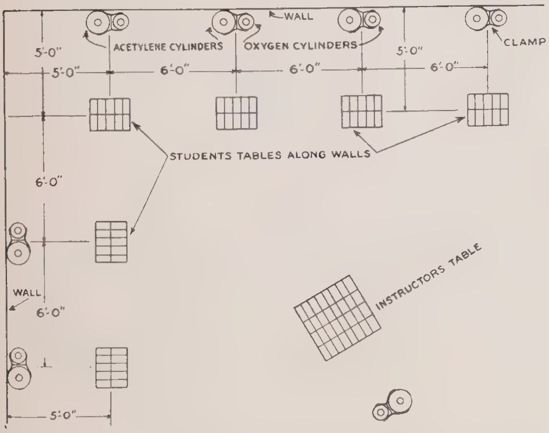
4,000 or 4,500 degrees in some instances, and these flames are useful for certain classes of work, such as lead burning, brazing, silver soldering and similar processes. They are not hot enough for welding, however, and no other gas flame has been discovered which will give, with like economy, a sufficiently high degree of heat to melt and control the various metals.

Torches, of course, while as accurately designed and manufactured as possible, are not perfect and cannot be made so on a commercial basis. Therefore, while the combustion of gases in the average torch closely approaches the theoretical proportion of one to one, in practical operation this proportion is not exact. They may consume slightly more acetylene or slightly more oxygen. The flame, however, is controlled by the torch valves and these must be kept in adjustment so that the flame by its appearance is in a balanced or neutral condition which is the term used for its characteristics when it is consuming essentially equal parts of the two gases delivered through the torch. This neutral or balanced condition is as near the theoretical welding flame as it is practicable to produce. It is neither oxidizing nor carbonizing but, of course, very hot and will burn metal if held too long in one place. If the regulators are working well and are set at the correct pressures, and the torch valves are properly adjusted, this neutral flame will continue to burn at the tip of the torch as long as required. Regulators, however, do not adjust with absolute precision and the pressures within the cylinders are constantly decreasing. Therefore, it is necessary from time to time to adjust either the torch valves or the regulator adjusting screw to maintain the flame constantly neutral in its characteristics. The neutral flame is used for almost all welding except in certain instances and these will be considered separately hereafter. Watching the flame and keeping it in its neutral condition is one of the most important requirements of welding.

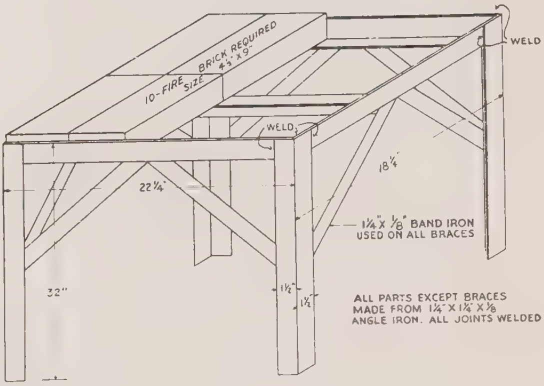
Too much oxygen will produce an oxidizing flame which will seriously burn the weld and decrease its strength. Too much acetylene, on the other hand, will produce a carbonizing flame having a lower flame temperature and delivering an excessive amount of carbon in contact with the hot metal; the result in this case will be a brittle weld.

Before closing this discussion it is desirable to emphasize certain precautions which every operator must keep in mind.

1. Keep the apparatus free from dust, dirt and grit.
2. Do not permit under any circumstances leaks in hose, regulator or torch connecting nuts and nipples.
3. Never open the cylinder valve without first being sure that the regulator adjusting screws are released.
4. Keep the torch flame pointing in a direction which will not injure your neighbor, the oxygen or acetylene cylinders or the hose.
5. Do not allow sparks or hot metal to fall or accumulate near the hose as it lies on the floor or the oxygen or the acetylene cylinders.
6. Take care of the tip seats and keep the port through the end of the tip clean and free from obstruction.
7. Learn to recognize instantly the neutral flame and to maintain it upon all occasions unless upon some special work which requires a flame differing in characteristics.
8. Hold the torch flame in relation to the metal, so that the luminous cone of flame does not actually come in contact with the surface of the metal. The tip of this flame should be close to the metal but should not actually have contact with it.



Plan of a Typical School Installation Showing Location of Cylinders and Welding Tables.


10-FIRE BRICK REQUIRED
SIZE 4½"x9"
WELD
WELD
18¼"
22¼"
1¼"x⅛" BAND IRON USED ON ALL BRACES
32"
1½"
1½"
ALL PARTS EXCEPT BRACES MADE FROM 1¼"x1¼"x⅛ ANGLE IRON. ALL JOINTS WELDED

Sketch of a Simple Welding Table for a School Installation.

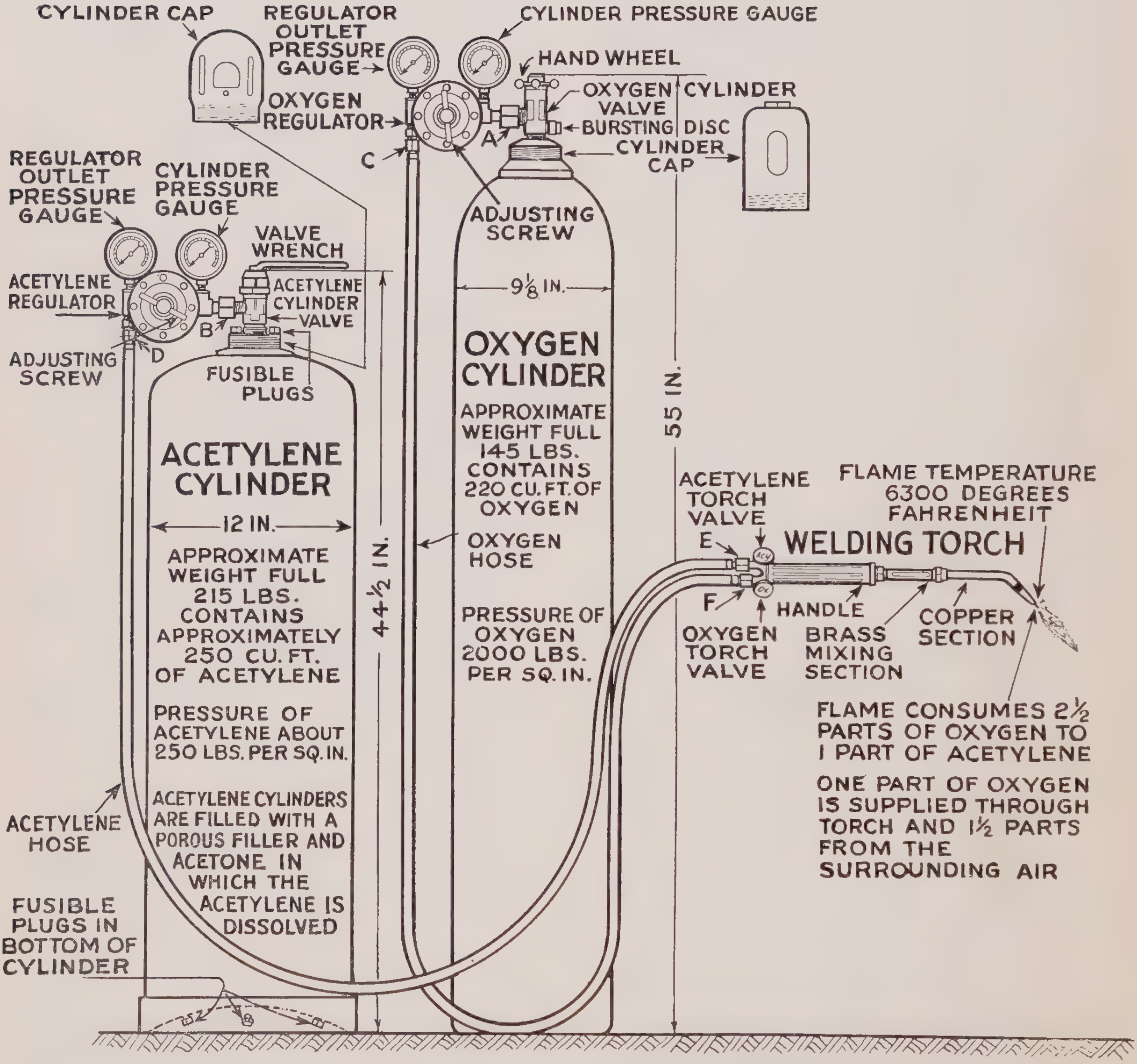

CYLINDER CAP
REGULATOR OUTLET PRESSURE GAUGE
CYLINDER PRESSURE GAUGE
HAND WHEEL
OXYGEN CYLINDER VALVE
OXYGEN REGULATOR
BURSTING DISC
CYLINDER CAP
A
C
ADJUSTING SCREW
REGULATOR OUTLET PRESSURE GAUGE
CYLINDER PRESSURE GAUGE
VALVE WRENCH
ACETYLENE REGULATOR
ACETYLENE CYLINDER VALVE
B
D
ADJUSTING SCREW
FUSIBLE PLUGS
9⅛ IN.
OXYGEN CYLINDER
APPROXIMATE WEIGHT FULL 145 LBS. CONTAINS 220 CU. FT. OF OXYGEN
ACETYLENE CYLINDER
12 IN.
APPROXIMATE WEIGHT FULL 215 LBS. CONTAINS APPROXIMATELY 250 CU. FT. OF ACETYLENE
44½ IN.
OXYGEN HOSE
55 IN.
PRESSURE OF OXYGEN 2000 LBS. PER SQ. IN.
PRESSURE OF ACETYLENE ABOUT 250 LBS. PER SQ. IN.
ACETYLENE CYLINDERS ARE FILLED WITH A POROUS FILLER AND ACETONE IN WHICH THE ACETYLENE IS DISSOLVED
ACETYLENE HOSE
FUSIBLE PLUGS IN BOTTOM OF CYLINDER
ACETYLENE TORCH VALVE
E
FLAME TEMPERATURE 6300 DEGREES FAHRENHEIT
WELDING TORCH
F
HANDLE
OXYGEN TORCH VALVE
BRASS MIXING SECTION
COPPER SECTION
FLAME CONSUMES 2½ PARTS OF OXYGEN TO 1 PART OF ACETYLENE
ONE PART OF OXYGEN IS SUPPLIED THROUGH TORCH AND 1½ PARTS FROM THE SURROUNDING AIR

Chart No. 1—Diagrammatic Sketch, showing Cylinders, Regulators and a Torch properly connected and ready to operate.

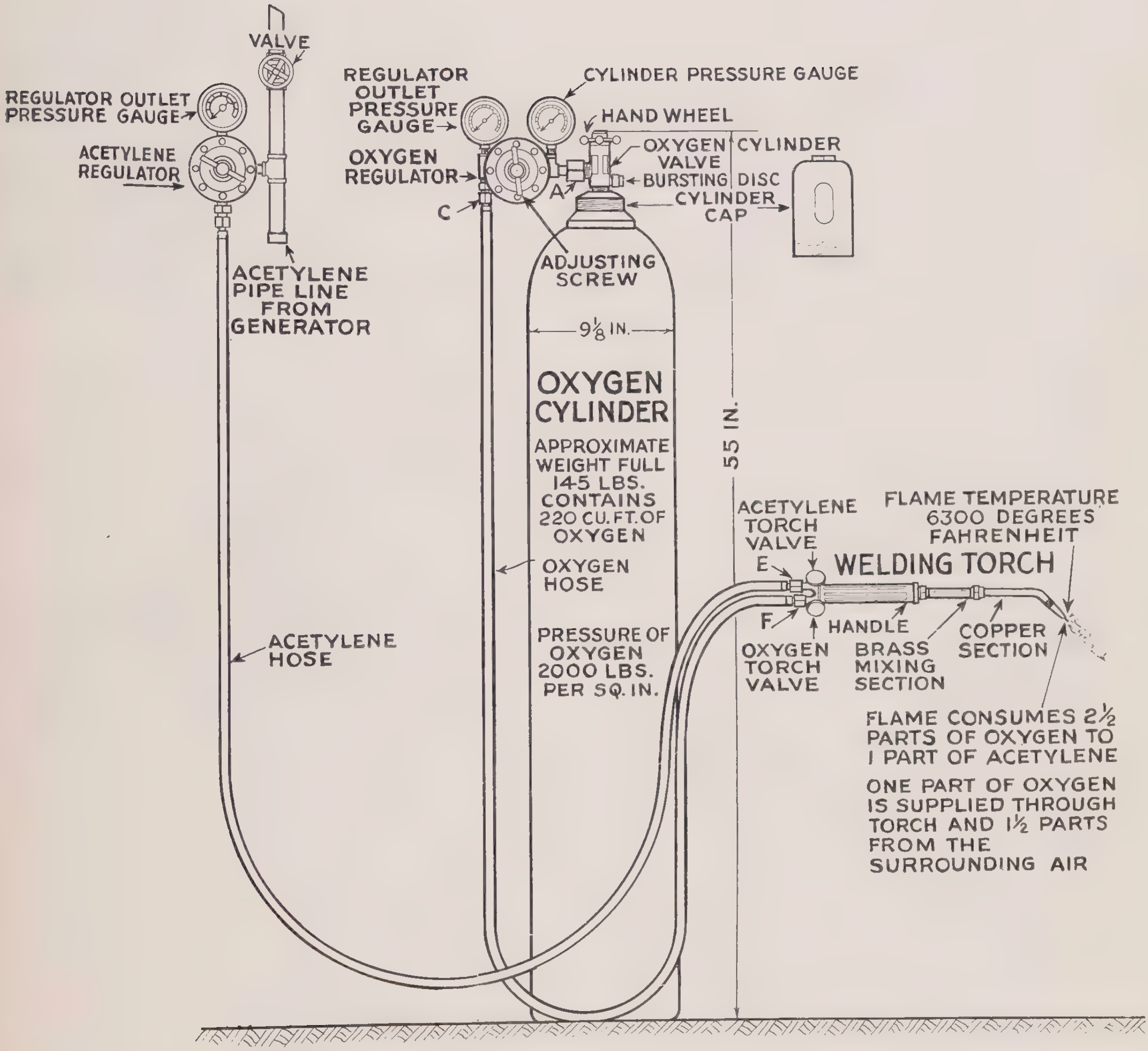

VALVE
REGULATOR OUTLET PRESSURE GAUGE
ACETYLENE REGULATOR
ACETYLENE PIPE LINE FROM GENERATOR
REGULATOR OUTLET PRESSURE GAUGE
OXYGEN REGULATOR
C
CYLINDER PRESSURE GAUGE
HAND WHEEL
OXYGEN VALVE
BURSTING DISC
A
CYLINDER
CYLINDER CAP
ADJUSTING SCREW
9⅛ IN.
OXYGEN CYLINDER
APPROXIMATE WEIGHT FULL 145 LBS. CONTAINS 220 CU. FT. OF OXYGEN
OXYGEN HOSE
PRESSURE OF OXYGEN 2000 LBS. PER SQ. IN.
55 IN.
ACETYLENE HOSE
ACETYLENE TORCH VALVE
E
F
OXYGEN TORCH VALVE
WELDING TORCH
HANDLE
BRASS MIXING SECTION
COPPER SECTION
FLAME TEMPERATURE 6300 DEGREES FAHRENHEIT
FLAME CONSUMES 2½ PARTS OF OXYGEN TO 1 PART OF ACETYLENE
ONE PART OF OXYGEN IS SUPPLIED THROUGH TORCH AND 1½ PARTS FROM THE SURROUNDING AIR

Chart No. 2—Diagrammatic Sketch showing the Equipment properly connected when the Source of Acetylene Supply is a Generator.

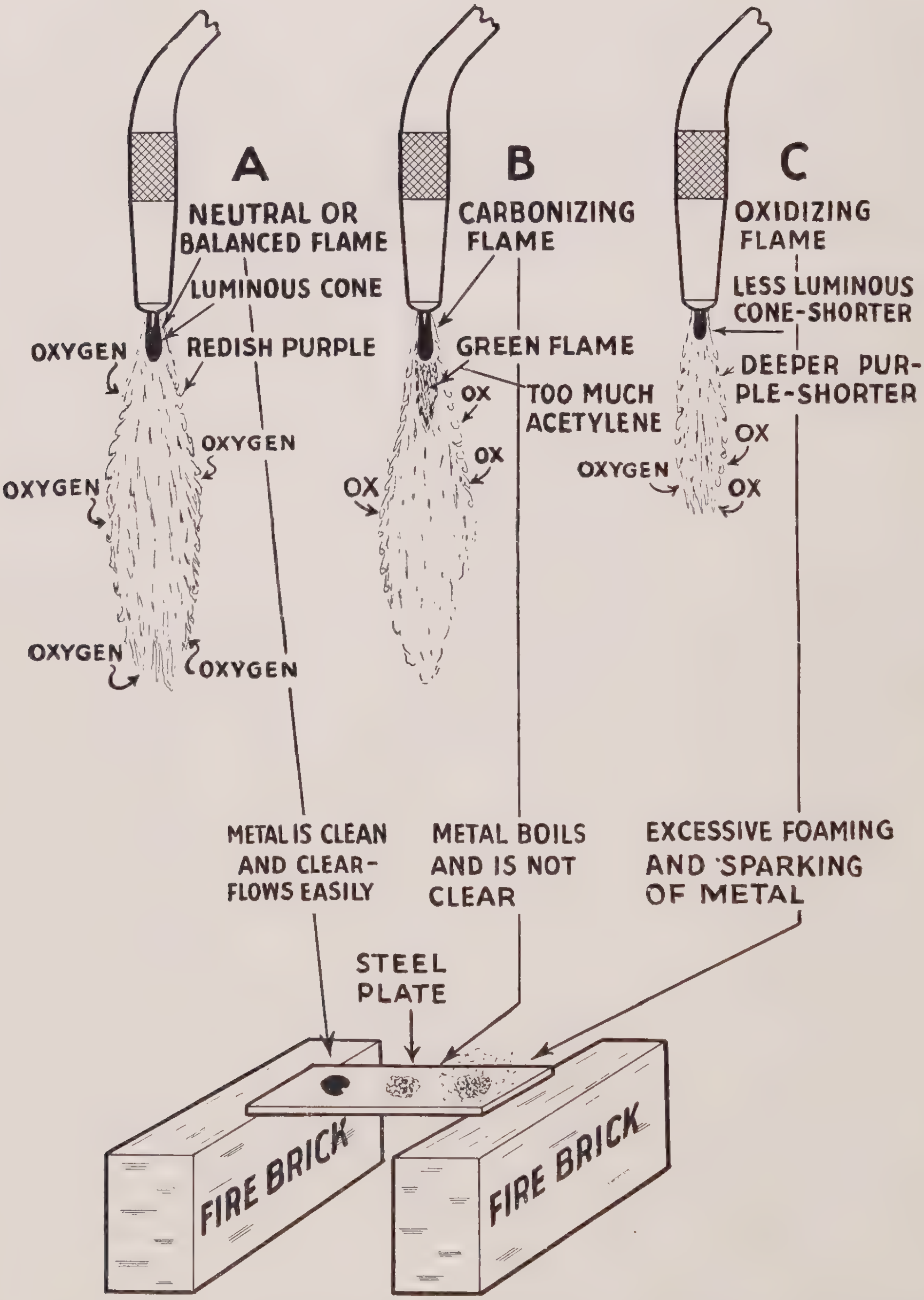
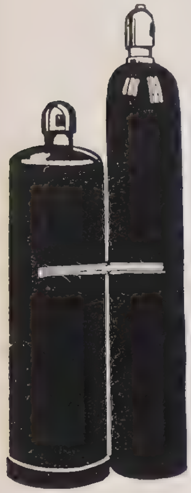
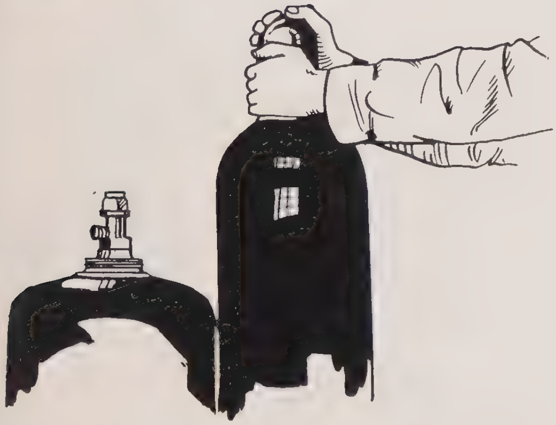

A
NEUTRAL OR BALANCED FLAME
LUMINOUS CONE
OXYGEN
REDISH PURPLE
OXYGEN
OXYGEN
OXYGEN
OXYGEN
B
CARBONIZING FLAME
GREEN FLAME
TOO MUCH ACETYLENE
OX
OX
OX
C
OXIDIZING FLAME
LESS LUMINOUS CONE-SHORTER
DEEPER PURPLE-SHORTER
OX
OXYGEN
OX
METAL IS CLEAN AND CLEAR-FLOWS EASILY
METAL BOILS AND IS NOT CLEAR
EXCESSIVE FOAMING AND SPARKING OF METAL
STEEL PLATE
FIRE BRICK
FIRE BRICK

Chart No. 3—Sketch illustrating Neutral, Carbonizing and Oxidizing Flames and the Effect of Each upon a Steel Plate.

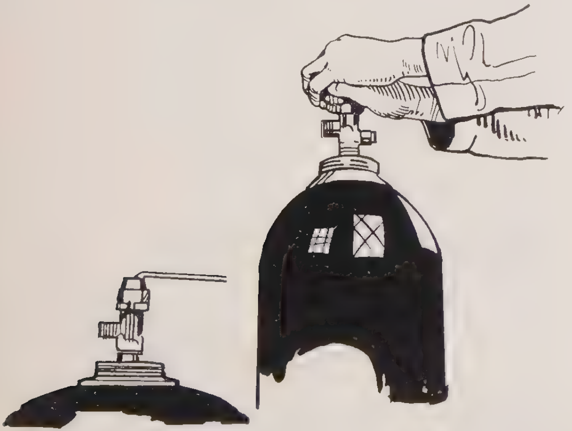
Twelve Steps in Setting Up Welding Equipment



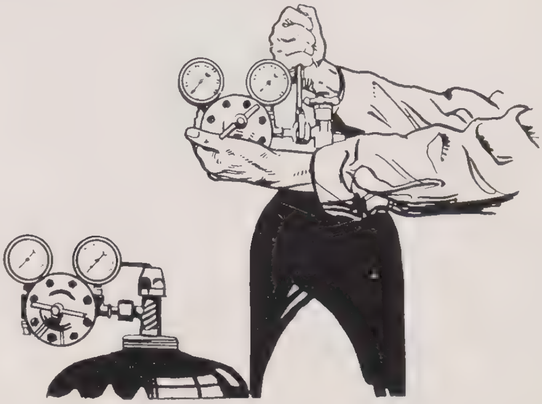
1. This is a view of the oxygen and the acetylene cylinders with the valve protecting caps in place. The oxygen cylinder has been placed to the right of the acetylene cylinder and close to it so that a clamp could be put in place fastening the two cylinders together to prevent tipping over.



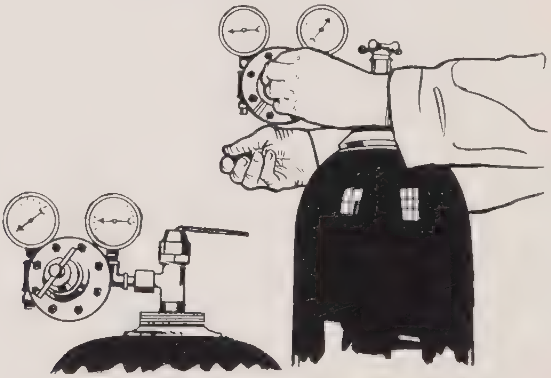
2. Removing the caps. Sometimes the caps stick in place and a wrench must be used to remove them. Often tapping slightly on the threads will assist.



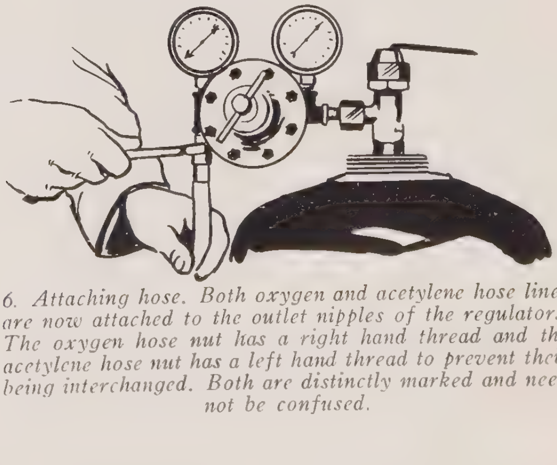
3. Opening the cylinder valves. Both oxygen and acetylene cylinder valves should be opened slightly and then quickly closed. This will blow out any dirt or grit which may have accumulated in the cylinder valve outlet nipples. Opening the valves in this manner before the regulators are put in place assures that the second time they are opened they will turn more easily and may be opened slowly.



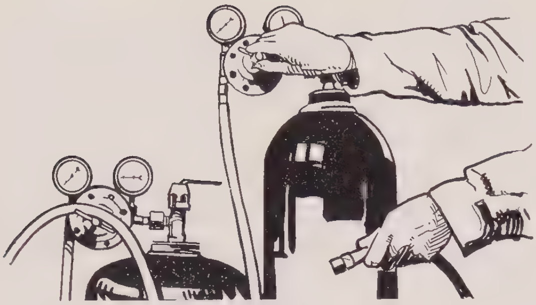
4. Attaching the regulators. Both oxygen and accetylene regulators are attached respectively to the cylinder valve outlet nipples of the two cylinders. To prevent attaching the wrong regulator to the cylinder, the threads on these regulator nuts differ. Be sure that these threads are not crossed and that the regulator inlet nipples are firmly in place in the outlet nipples of the cylinder valves. Screw up the regulator connecting nut with a wrench until the union is gas tight.



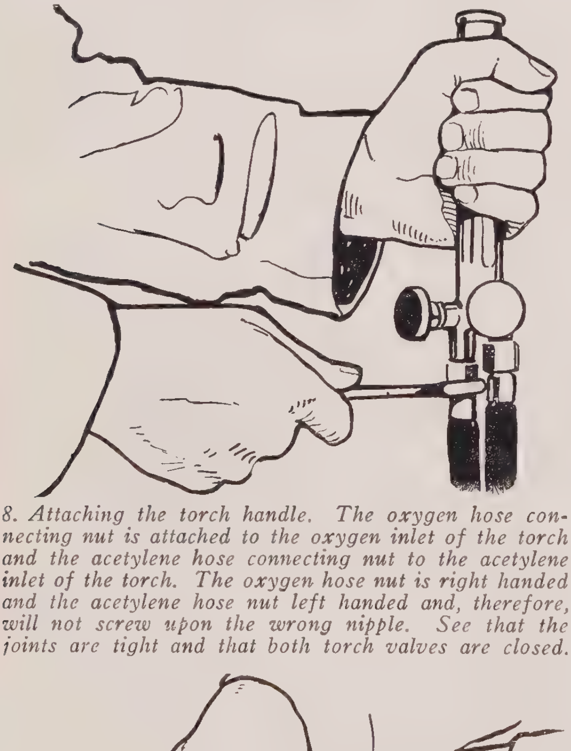
5. Blowing out the regulators. Both adjusting screws are fully released by turning them to the left until there is no pressure upon the regulator spring within the bonnet. Cylinder valves are then slowly opened permitting the gases to enter the regulators. A slight turn to the right of each regulator adjusting screw will then slightly open the regulator valve or seat and permit the escape of the gases through the outlet nipples of the regulators. The adjusting screws are then again released.



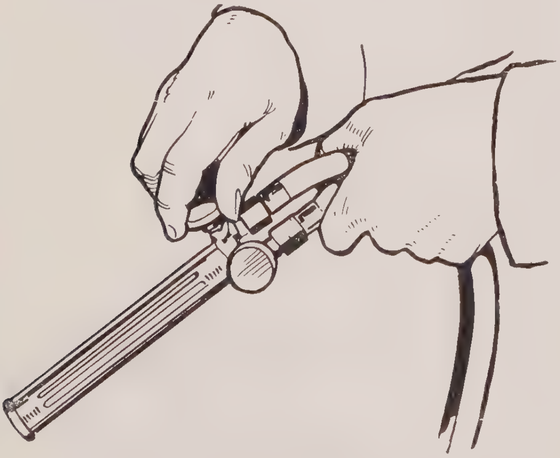
6. Attaching hose. Both oxygen and acetylene hose lines are now attached to the outlet nipples of the regulators. The oxygen hose nut has a right hand thread and the acetylene hose nut has a left hand thread to prevent their being interchanged. Both are distinctly marked and need not be confused.



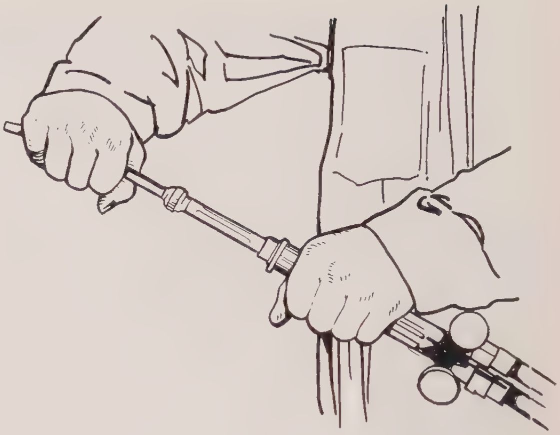
7. Blowing out hose. It is essential that no grit or dirt be allowed to remain in the hose and blown into the torch. Therefore, before the torch is attached it is good practice to blow out each line of hose by turning the regulator adjusting screws to the right until gas escapes from the end of the hose. Turn them to the left again when just enough gas has escaped to serve the purpose. Remember acetylene is inflammable and must not be allowed to catch fire.



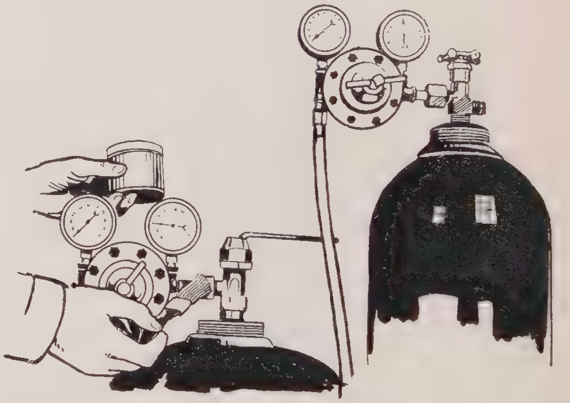
8. Attaching the torch handle. The oxygen hose connecting nut is attached to the oxygen inlet of the torch and the acetylene hose connecting nut to the acetylene inlet of the torch. The oxygen hose nut is right handed and the acetylene hose nut left handed and, therefore, will not screw upon the wrong nipple. See that the joints are tight and that both torch valves are closed.



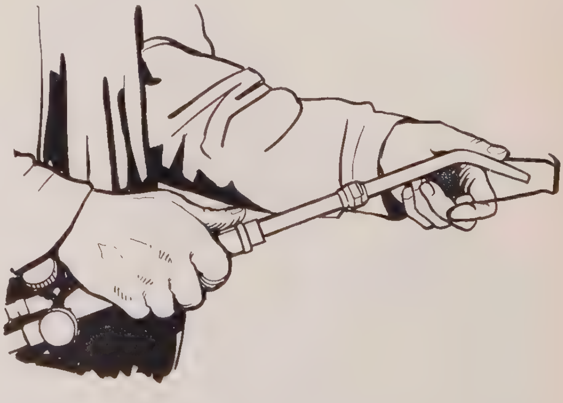
9. Blowing out the torch handle. This removes any grit or dirt in the passages. Open but one valve at a time. Both torch valves should not be opened at the same time until the torch is lighted.



10. Attaching tips. A tip of the proper size is screwed into the torch handle until it is tightly in position and the operator is sure that all joints will not leak gas.



11. Testing joints with soap and water. When the operator first sets up equipment and until he is sure that all connections are gas tight, it is good practice to test each joint with soap suds. With a small brush the soap and water are worked into a lather and this lather applied to each joint. Escaping gas will immediately show a soap bubble.



12. Lighting the torch. After regulators have been set at suitable pressures for the tip in use, as described in Job Sheet No. 1, the torch is lighted with a spark lighter.

Job Sheet No. 1

Setting Up the Equipment

The operator should be dressed in a suitable work coat or overalls and be provided with leather or canvas gloves and goggles or spectacles.

1. See that the following equipment is available:

1—Oxygen cylinder
1—Acetylene cylinder
1—Oxygen welding regulator
1—Acetylene regulator
2—Lengths of hose
1—Welding torch and 5 assorted sizes of tips
1—Acetylene cylinder valve wrench
1—Regulator and torch wrench
1—Spark lighter
(It is presumed that a welding table, two fire bricks and pieces of 16 gauge steel plate 1 inch x 6 inches have already been provided.)

2. Set the oxygen cylinder to the right of the acetylene cylinder and either clamp them together with a suitable clamp or chain them separately to the wall or a post to prevent tipping over.

3. Remove the cylinder caps from both the oxygen and acetylene cylinders. These cylinder caps are used to protect the cylinder valve during shipment and should be placed where they may be readily found again when the cylinders are empty and are to be returned to the recharging station or warehouse from which they were procured. (Some acetylene cylinders have a fixed cap or protecting ring which does not interfere with attachment of the acetylene regulator.)

4. Slightly open both the oxygen cylinder valve and the acetylene cylinder valve, using the valve wrench in the latter case. Opening of the valves in this manner assures that they will open easily and that any dirt or grit in the valve outlet will be blown out. The valves should be closed immediately after they have been slightly opened and a little gas allowed to escape. Remember that acetylene gas is inflammable and will ignite if it comes in contact with sparks or flame.

5. Attach the oxygen regulator to the outlet of the oxygen cylinder valve using the regulator wrench to be sure that the connecting nut "A" (see chart No. 1) is tight.

6. Unscrew the adjusting screw of the oxygen regulator by turning it to the left until it turns easily—that is until all pressure upon the spring upon which it rests has been released. The seat or valve in the oxygen regulator is now closed. Slowly open the oxygen cylinder valve, unscrewing it several turns upon certain types of valves until any leakage upward through the bonnet is stopped. Some types of valves will not leak through the bonnets whether in an open or closed position. Others require unscrewing several turns until pressure is brought to bear upon a rubber disk around the spindle thus preventing leakage by this part. The full pressure within the cylinder, namely, about 2,000 lbs. per square inch, is now apparent upon the dial of the cylinder pressure gauge.

7. Turn the adjusting screw of the oxygen regulator to the right a few turns until a little pressure is placed upon the spring within the regulator, thus opening the valve and allowing a little oxygen to escape from the regulator outlet. This will blow out any dirt or grit which may have accumulated in the outlet nipple.

8. In similar manner connect the acetylene regulator to the outlet nipple of the acetylene cylinder valve, being sure that the connecting nut "B" (see chart No. 1) is tight, release the adjusting screw of the acetylene regulator and open the acetylene cylinder valve with the valve wrench one or two turns. Screw the adjusting screw of the acetylene regulator to the right until a little pressure is placed upon the spring and the valve begins to open, delivering a small quantity of acetylene through the outlet nipple. This will blow out any dirt or dust in the nipple, but the adjusting screw should be immediately released to prevent the escape of acetylene into the room.

9. Attach the oxygen hose, having a right hand connecting nut, to the oxygen regulator outlet, and the acetylene hose, having a left hand connecting nut, to the acetylene regulator outlet. These hose nuts cannot be interchanged because they are provided with right and left hand threads to prevent the wrong hose from being placed upon the regulator. They are distinctly marked so that they can be readily recognized. Using the regulator adjusting screws, blow a little oxygen and acetylene respectively through their separate lines of hose to blow out any dirt or grit which have collected in the hose. Do not unnecessarily waste the oxygen and remember that too much acetylene must not be allowed to escape into the room.

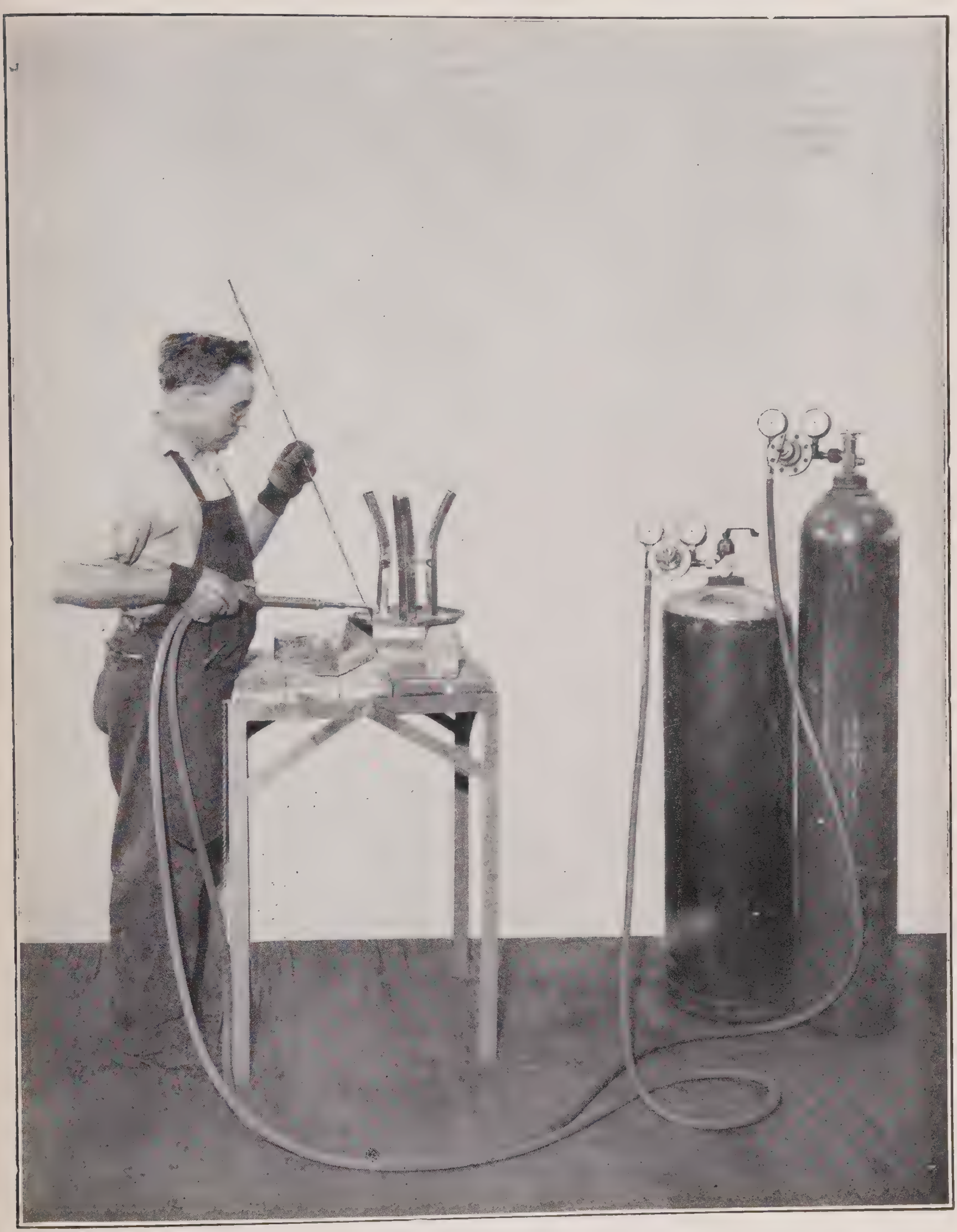
10. Connect the oxygen hose to the oxygen inlet of the torch handle and the acetylene hose to the acetylene inlet of this handle. Note that the oxygen connecting nut is right handed and the acetylene nut left handed. These are distinctly marked so that they will not be placed upon the wrong inlet nipple. See that all nuts are wrench tight. Open the torch valves separately, and with the adjusting screws on the regulators blow a little oxygen and a little acetylene through the torch handle to remove any grit or dirt

which may have accumulated. Close both torch valves.

11. Select a small size tip suitable for the metal to be used, as shown by the manufacturer's tables usually to be found in the catalog or upon a wall chart, and insert this tip properly into the handle. Be sure that the tip connection is tight and that other joints in the torch have been made tight.
12. Provide a brush and a small can or cup of soap suds. A small piece of soap and a little water is sufficient. Test all joints with soap suds for leakage. If any leaks are found, stop them. If you cannot do this by normal means notify your instructor.
13. Look at the manufacturer's pressure chart for the tip in use and determine the proper pressure of oxygen and acetylene for the tip which has been placed in the torch. Open the oxygen torch valve and screw in the adjusting screw of the oxygen regulator until this pressure shows upon the regulator pressure gauge. Close the oxygen torch valve. Open the acetylene torch valve, screw in the adjusting screw of the acetylene regulator until the proper pressure shows upon the outlet pressure gauge and light the acetylene, flowing from the tip of the torch, with the spark lighter.

    Do not unnecessarily allow acetylene to escape into the room. If no charts are available showing the proper acetylene pressure, or if there is no outlet pressure gauge upon this regulator, the acetylene may be adjusted until the flame burning from the tip just begins to leave the tip. The oxygen torch valve may then be turned on and as the oxygen mixes with the acetylene and increases combustion at the tip of the torch the long, smoky flame, caused by the acetylene only, will change in color to a reddish purple with a brilliant, well defined, luminous cone of flame immediately at the end of the tip. This flame normally should be neutral in character if the regulator pressures are correct, but usually a little further adjustment of the torch valves is necessary to eliminate entirely the green tinge of flame caused by too much acetylene, or to reduce the supply of oxygen.
14. Adjust the flame, if necessary, until sure that it is neutral in character, as shown at "A" on chart No. 3. This chart illustrates the principle characteristics of the flame developed at the torch. It also shows the effect of these three flames upon the metal. "A" is the neutral or balanced flame which is used in almost all instances for the welding of steel and for general purposes. It is the correct flame which will neither oxidize nor carbonize the metal. "B" is a carbonizing flame to which too much acetylene has been supplied. Besides the luminous cone and the secondary envelope of burning gases normally in the neutral flame, there is an additional green tinge of flame extending from the luminous cone indicating too much acetylene. By cutting down the acetylene supply with the acetylene torch valve, this green flame can be caused to disappear entirely, resulting in the neutral flame shown at "A." "C" is an oxidizing flame. The luminous cone is much shorter and is less luminous. The oxidizing flame is caused by too much oxygen. The envelope of the flame becomes a deeper purple and is very much shorter. The oxidizing flame "C" is caused by delivering too much oxygen and too little acetylene through the torch. This may be the result of improper setting of the pressures at the regulators or improper adjusting of the torch valves. An oxidizing flame will burn the weld and the adjacent metal and cause a porous and oxidized weld which is lacking in strength.

    The carbonizing flame "B" on the other hand is caused by the delivery of too much acetylene through the torch. The carbon contained in this excess of acetylene contacts with the hot metal and makes it mottled or pitted in appearance and brittle. The carbonizing flame is used in some instances for certain classes of work, but it should only be used when it is known that the effect of an excess of acetylene is beneficial. Neither the carbonizing flame "B" nor the oxidizing flame "C" are used under any circumstances in the welding of cast iron or steel. For this class of work the correct flame is the neutral or balanced flame "A."
15. With the torch lighted as heretofore apply the flame to a piece of steel resting on two fire bricks, as shown in chart No. 3. First, adjust the flame to the neutral or balanced condition, as shown in "A," and move the torch near the steel plate until the luminous cone of flame closely approaches the metal but does not touch it. The spot under the flame will become red hot very quickly and will soon melt. The metal will be clean and clear and will flow easily like syrup. The molten metal will lie quietly beneath the flame.
16. Open the acetylene valve to allow a little more acetylene to pass through the torch, or if necessary turn in the adjusting screw of the acetylene regulator slightly to deliver more acetylene to the torch. This will produce a carbonizing flame, "B," with the excess of acetylene and the green flame which indicates this condition. Apply this flame to the metal and note how the metal boils and is cloudy after it has become hot. Note this condition so that it will be readily recognized and learn to avoid a carbonizing flame.



One of the First Things which a Student Must Learn is to Stand Up Straight when Welding. The Work Should be Placed, Supported by Fire-Brick, Resting on Top of the Table, Slightly Lower than the Level Made by a Man's Bent Elbow, as Shown in this Photograph. When He Stands in this Manner, the Student is Erect and in a Comfortable Position, Which He can Maintain for a Long Period of Time. If he is Bent Over His Work His Back will Soon Give Out, and the Heat from the Torch and the Weld is Likely to Burn his Face. This Photograph Shows Oxygen and Acetylene Cylinders, Regulators, Hose, the Torch and a Welding Table. A Milk Stool is Set Upon Fire-Bricks in a Convenient Position for Welding.

17. Turn on the oxygen torch valve, or screw in the adjusting screw of the oxygen regulator slightly to produce an excess of oxygen. Note the change which takes place in the flame—it becomes harsh, less luminous and the envelope a shorter flame and a much deeper purple in color—the flame roars spitefully, and when applied to the metal there is an excessive sparking and foaming. Combustion is unbalanced because of the excess of oxygen. The flame consumes all of the oxygen which it possibly can, but as there is an excess which cannot be consumed the hot metal is attacked by it and oxidized or burned. A weld made with an oxidizing flame will lack strength. Watch the effect of the oxdizing flame on the metal and learn to avoid this flame under all conditions. It is this flame which more than anything else causes poor, weak welds.

18. Select a new piece of metal and lay it over the fire bricks and adjust the torch to the three flames again and apply them to the metal. Note again their different characteristics and how each of them affects the metal in a wholly different way. Do this several times until the difference between these flames is clearly understood and recognized instantly. Knowledge of flame characteristics and the ability to adjust a flame until it is neutral and to maintain it in this condition is essential to good welding.

19. When ready to turn off the torch the following procedure should be invariably followed: (a) Close the acetylene torch valve. (b) Close the oxygen torch valve. (c) Hang up the torch on a suitable hook or rack provided for the purpose.
    If the torch is to remain off any length of time, the pressure should be released from the regulators. This is done by closing the acetylene cylinder valve, opening the acetylene torch valve and allowing the acetylene to escape from the regulator and hose. The adjusting screw on the acetylene regulator should then be turned to the left until pressure on the spring is released. The acetylene torch valve should now be closed. In similar manner the oxygen cylinder valve should be closed, the oxygen torch valve opened and the pressure within the oxygen regulator and hose allowed to escape. The adjusting screw of the oxygen regulator should then be turned to the left until pressure upon the spring is entirely relieved and the oxygen torch valve should then be closed. It is important that both torch valves be kept closed when the torch is not in operation. Remember this and do not leave them open.
    Caution—It is very important that the operator realize when he has a lighted torch in his hand that he has a weapon which may cause serious injury to others or damage to property if not carefully handled.
    The flame is very hot and it must not be pointed at a neighboring operator or at the hose or the cylinders. The operator should always keep in mind that he has dark glasses over his eyes and that it is very easy to direct the flame where it may do damage. Carelessness with a welding torch, or with welding or cutting equipment must never be permitted.

Lesson No. 1 should be read and reread by the operator until he is thoroughly familiar with it.

Questions:

1. Will oxygen burn?
2. Will acetylene burn?
3. Why are oxygen and acetylene used together to produce a hot flame?
4. What proportion of these gases is used to produce a neutral flame?
5. What part of the oxygen consumed by the flame passes through the torch?
6. Why is a neutral flame used for most welding of iron and steel?
7. How does the neutral flame appear?
8. What should an operator particularly guard against when he has a lighted torch in his hand and goggles over his eyes?
9. How does the metal act when a neutral flame is brought close to it?
10. Which gas is turned off first when shutting down equipment?

Lesson No. 2

Welding Torches and Regulators

IN Lesson No. 1 the student was taught how to connect up a welding outfit, how to light the torch and how to adjust the flame to a neutral or balanced condition. He was also shown the effect of neutral, carbonizing and oxidizing flames upon a plate of steel. In this lesson he will have the opportunity to use the neutral flame to join together or weld two pieces of No. 16 gauge sheet steel about one-sixteenth of an inch in thickness. Job Sheet No. 2 describes this procedure. It is the simplest form of welding and requires no adding material or welding rod, except when required for tacking the plates together before the weld is started.

It is essential that the student practice this exercise over and over until he becomes thoroughly familiar with the heat developed by the torch and is able to control the metal when it becomes molten. The two pieces of sheet steel, six inches long and one inch wide, are set upon the fire bricks, as shown in Fig. No. 1 and tacked at each end. The weld is then started at the right hand edge of the metal and continued from right to left. In this manner a corner weld is made.

Ripple Welding

Beginning at the right hand edge of the seam a puddle is formed by bringing the luminous cone of the flame to within about one-sixteenth of an inch of the metal and melting the edges. This puddle should be about one-eighth of an inch in width and should be made by moving the torch along the seam with a slow crosswise motion. The puddle of molten metal will progress with the forward movement of the torch and the slow crosswise movement will help to join the molten edges of the two sheets. In this manner a ripple weld (see Figs. 3 and 4) is formed, but it should not be thought that the cross motion of the torch or any oscillating motion is necessary to produce a ripple weld. As a matter of fact, a ripple will be made if the torch is held perfectly steady, but progressing evenly forward along the seam.

A ripple weld is not the result of any specific movement of the torch, or of a filler rod if this is used. The ripple weld is the result of melting a round puddle in metal and moving this melted puddle along the surface. If the puddle is circular, the back edge will cool in smooth, even ripples. If the puddle is not round, the back edge of it will not be round and the ripple will be irregular.

As the weld is made, the torch must move forward slanting at an angle of approximately 45 degrees towards the direction of movement, that is, from right to left, and at the same time slowly backward and forward across the weld. If the puddle becomes too wide, the rate of forward motion of the torch should be increased. If the puddle becomes too narrow and not sufficiently deep to penetrate clear through the metal, the speed should be decreased until the torch is moving just rapidly enough to fuse clear through the sheet and form an even, smooth puddle as it progresses. The result will be a ripple corner weld made without filling material.

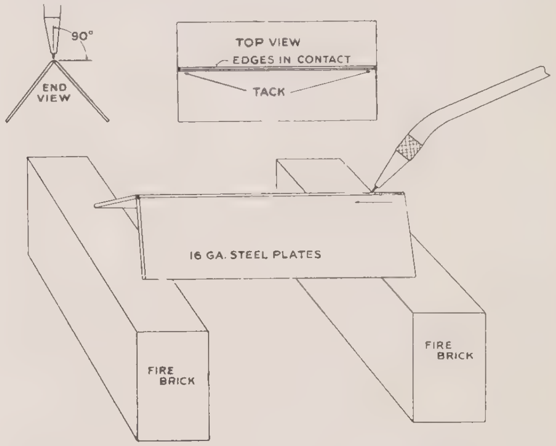


Figure 1—Sketch Showing Method of Making a Ripple Corner Weld. Two Pieces of No. 16 Gauge Sheet Steel, One Inch in Width and Six Inches Long, Are Set at a Right Angle to Each Other Across the Two Supporting Bricks and Corner Welded With the Torch.

If, of course, the operator should accidentally burn a hole through the metal, or if the weld becomes too low to be even, a little metal from a filling rod should be added.

The second job of this lesson also described in Job Sheet No. 2, consists in placing two pieces of one-sixteenth inch sheet steel flat on the bricks and tacking each end to keep them in position as shown in Fig. 2. The torch is then applied, keeping the flame about one-sixteenth inch from the metal and slanting about 45 degrees in the direction of welding, that is, from right to left. The puddle should be started at the edge and the torch moved evenly forward without any cross motion, the speed being just enough to fuse clear through the metal and form a progressing puddle of even width and size. As the metal hardens after the torch has passed over it, the back rim of the puddle will form even, smooth ripples and a ripple butt weld, made without adding material, will be the result.

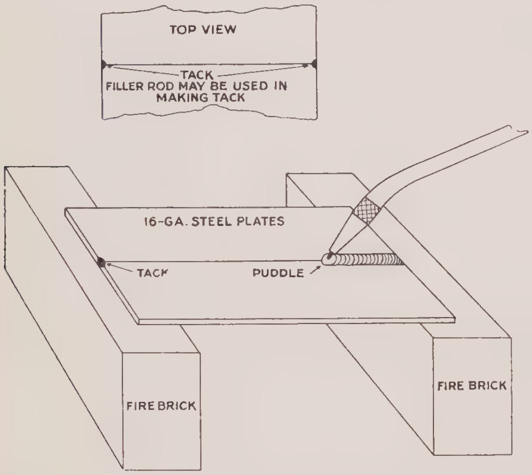


Figure 2—Sketch Showing Method for Making a Butt Weld in 16 Gauge Steel. Two Similar Pieces of Sheet Steel Are Placed Edge to Edge Flat Across the Bricks and a Butt Ripple Weld Made Between Them.

Welding Rods

The most convenient size of sheet steel for these practice jobs is made by obtaining scraps of No. 16 gauge sheet steel from a shear. These are cut into pieces six inches long and one inch wide. The welding rod to be used should be $\frac{1}{16}$ inch in diameter and is usually furnished in thirty-six inch lengths. It should be a low carbon steel wire, conforming to the specification of the American Welding Society, G-No. 1A. This specification shows an analysis as follows:

Carbon	not over 0.06 of one per cent
Manganese	not over 0.15 of one per cent
Phosphorus	not over 0.04 of one per cent
Sulphur	not over 0.04 of one per cent
Silicon	not over 0.08 of one per cent

Welding rods of these specifications can be obtained from almost any manufacturer or jobber of equipment or welding supplies. Baling wire, hay wire, or other steel wire of unknown chemical content should not be used. Such practice will usually result in poor welds and general dissatisfaction.

Size of Tips

The selection of the proper size of tip for the work to be accomplished is extremely important. It is obvious that when welding sheet steel $\frac{1}{16}$ inch in thickness a small tip, producing a small welding flame should be used. When welding thicker metal a larger tip producing a flame greater in size in proportion to the thickness of the metal should be used. For the foregoing jobs a welding torch handle and a No. 1 tip assembly are recommended, as the flame produced by this tip is suitable in size for the $\frac{1}{16}$ inch pieces of steel. (See chart No. 4.)

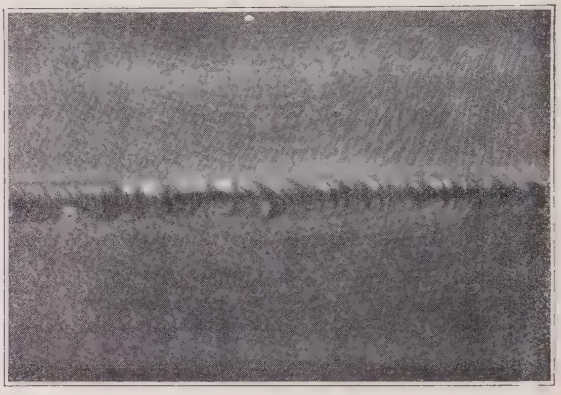


Figure 3—This is a Photograph of the Finished Corner Ripple Weld Made According to the Method Illustrated in Fig. 1 and Described in This Lesson.

Tip sizes differ, of course, and where other makes of equipment are in use, it will be necessary for the student to consult the manufacturers' chart or table, which will usually be found in their various catalogs. For convenience, Chart No. 4 illustrates the various sizes of tip assemblies which can be procured for an average welding torch and the size of the flame produced by each of these tips. As this torch is constructed

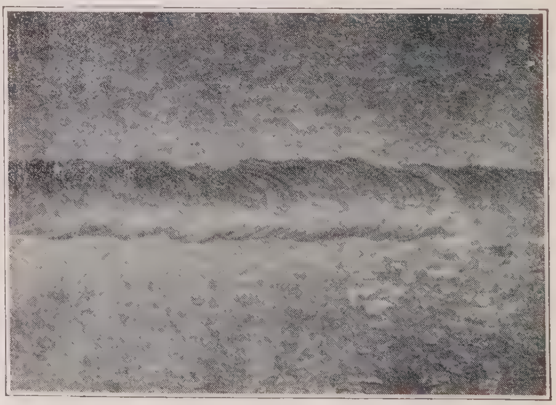
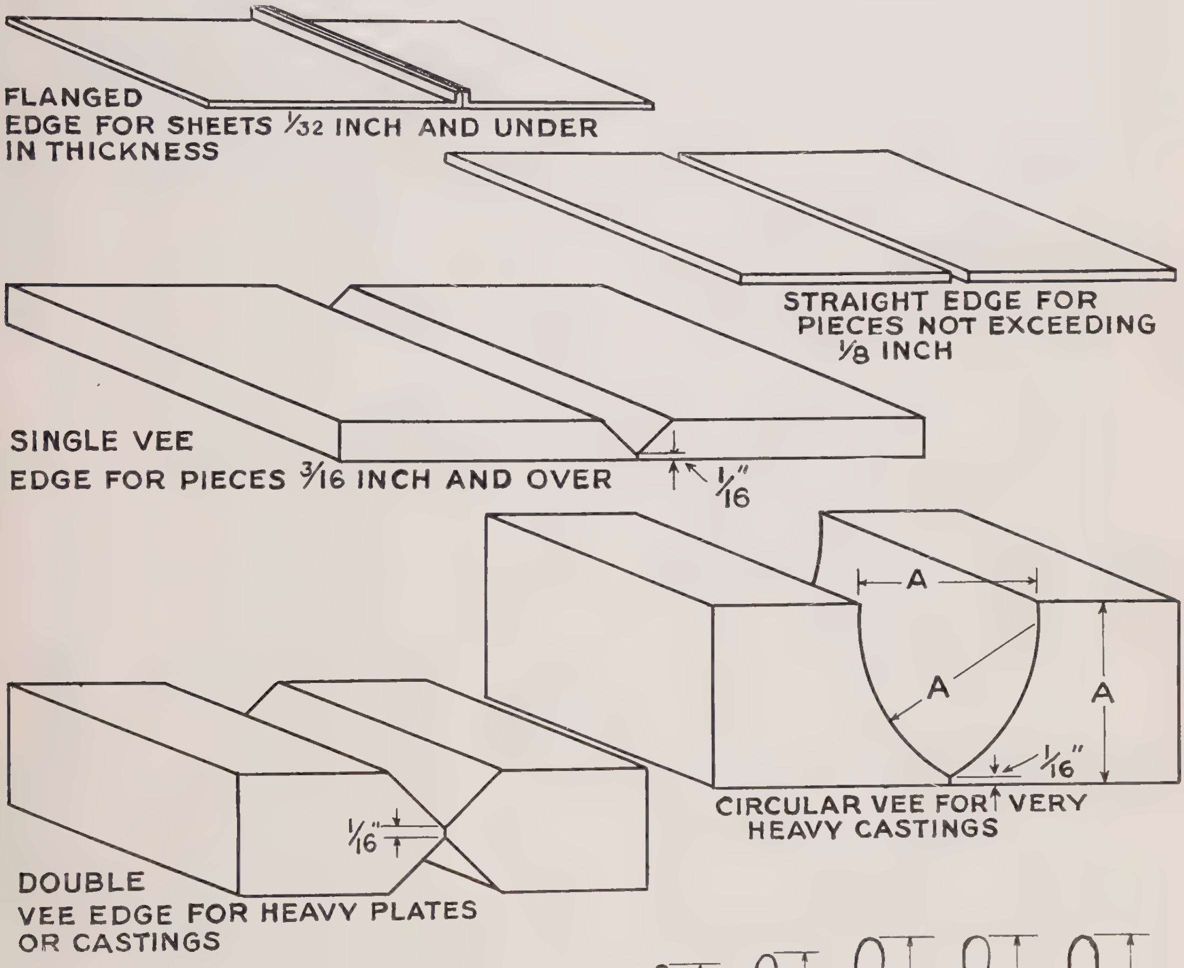
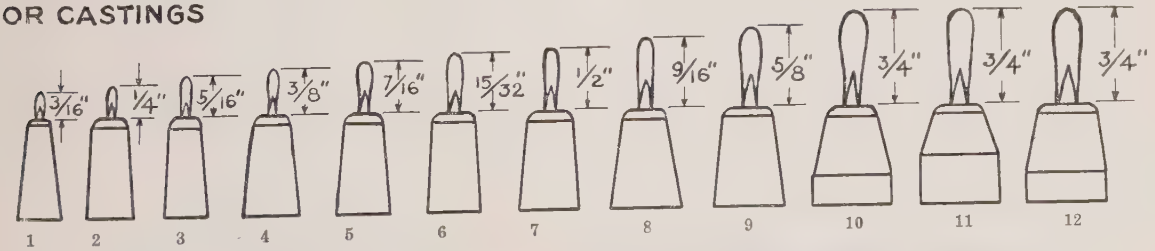


Figure 4—Photograph of the Completed Butt Ripple Weld Heretofore Described and Illustrated. The Student Should Practice These Welds Until He Can Make Them as Evenly and Smoothly as is Shown in the Photograph.

Table Showing Gas Consumption, Length of Flame, Regulator Pressures, Etc., for Each Size of Tip Assembly

Size of Tip Assembly	Thickness of Metal in Inches	Length of Ave. Flame in Inches	Approximate Pressure at Regulators in Pounds per Square Inch		Main Port Drill Size	Dia. of Main Port in Inches	Approximate Cu. Ft. of Gas Used per Hour		Approx. Number of Lineal Feet Welded per Hour	Size of Tip Assembly
			Oxy.	Acet.			Oxy.	Acet.		
1	1/16	3/16	1	1	63	.037	5.0	5.0	13.0	1
2	1/16 to 1/8	1/4	2	2	58	.042	6.0	6.0	18.5—5.8	2
3	1/8 to 3/16	5/16	2	2	54	.055	9.0	9.0	12.0—3.0	3
4	3/16 to 1/4	3/8	3	3	52	.0635	12.0	12.0	10.2—3.5	4
5	1/4 to 3/8	7/16	4	4	48	.076	21.0	21.0	8.3—7.5	5
6	3/8 to 1/2	15/32	5	5	44	.086	23.0	23.0	4.2—2.3	6
7	1/2 to 5/8	1/2	6	6	40	.098	36.0	36.0	3.1—2.0	7
8	5/8 to 1	9/16	7	7	36	.1065	50.0	50.0	2.1—1.7	8
9	1 and over	5/8	8	8	32	.116	58.0	58.0	Variable	9
10	Heavy Castings, Etc.	3/4	9	9	28	.1405	100.0	100.0		10
11		3/4	10	10	26	.147	106.0	106.0		11
12		3/4	11	11	25	.1495	108.0	108.0		12


FLANGED
EDGE FOR SHEETS 1/32 INCH AND UNDER
IN THICKNESS
STRAIGHT EDGE FOR
PIECES NOT EXCEEDING
1/8 INCH
SINGLE VEE
EDGE FOR PIECES 3/16 INCH AND OVER
1/16"
A
A
A
1/16"
CIRCULAR VEE FOR VERY
HEAVY CASTINGS
1/16"
DOUBLE
VEE EDGE FOR HEAVY PLATES
OR CASTINGS


3/16"
1/4"
5/16"
3/8"
7/16"
15/32"
1/2"
9/16"
5/8"
3/4"
3/4"
3/4"
1
2
3
4
5
6
7
8
9
10
11
12

SKETCH SHOWING THE AVERAGE SIZE OF FLAME FOR EACH SIZE OF TIP

Chart No. 4—This Chart Shows the Average Size Flame Produced by Each Tip When the Regulators Are Set at the Pressures Given. It Also Gives the Drill Sizes and the Diameters of the Various Sizes of Tips, the Method for Preparing Various Thicknesses of Metal, the Average Speed of Welding and the Approximate Consumption of Oxygen and Acetylene of Each Size of Tip.

to use equal pressures of oxygen and acetylene, the two pressures are the same for each tip, but vary with the size of the tip. These approximate pressures are also given in Chart No. 4.

Flames Should Be Average Size

It should be understood, however, that the size of flame shown in this chart, produced by the pressures as set forth, is an average size flame for each tip. By increasing or decreasing the pressures given, the flame size can be increased or decreased. If it is increased too much the pressure of the gases will cause the flame to "blow," or in other words, issue from the tip so rapidly that the force of the burning gases is likely to blow away the hot metal of the weld and make it difficult to control. On the other hand, if the pressures upon the gases are lowered too much, thereby decreasing the size of the flame, they may become so low that the flame will "pop" out if the tip is accidentally brought too close to the metal. The flame size shown is, therefore, the average normal flame which should be used for each size of tip and the pressures given are those which will produce a flame of this size. Such a flame is soft and neutral. It does not "blow" the metal, and if the tip is brought accidentally into contact with the plate or the hot metal it will resist back-fire or "popping out" to a maximum extent.

Thickness of Metal

Having determined the size of the flame produced by the various tips, the next step is to set forth the thicknesses of metal for which each size of flame is best suited. Of course, the thicker the metal, the greater is the amount of heat required to melt it, and for this reason the size of the flame must increase in proportion to this thickness. There is, of course, a considerable overlapping of the thicknesses of metal which each tip will properly weld and for this reason the approximate maximum and minimum thicknesses are given for each tip size. These will be found in Chart No. 4.

The student should have a rough idea of how fast a weld of a definite thickness should be made, and also approximately how much oxygen and acetylene is consumed by each tip. These figures have been approximately determined and are set forth in detail upon Chart No. 4.

It should be understood that all figures pertaining to the thickness of metal, the consumption of gases by the tip and the speed of welding must of necessity be rough approximations. Each make of equipment utilizes, through the tips, ports which differ in size and for this reason the sizes of the flames for tips of similar number vary to a considerable extent. Furthermore, the consumption of gas will, of course, vary with each different size of flame and hence with each make of apparatus.

There are other factors which determine the size of flame required upon certain work and one of these is the conductivity* of the metal. A metal which conducts the heat rapidly will require a larger flame. Furthermore, a large casting where there is a considerable mass of metal will require more heat to heat the break being welded to a welding temperature than a small piece.

Chemistry of the Flame

As has been stated before, the combustion of pure oxygen and acetylene produces the most remarkable flame ever supplied for certain applications of heat to metal. This flame was described in Lesson No. 1 and a few general remarks were made with reference to the correct proportion of the gases to produce the flame.

The chemical reaction of this flame, illustrated in Fig. 5, is very simple and without going into chemical formulas is as follows: To burn one volume of acetylene completely requires two and one-half volumes of oxygen and the combustion produces two volumes of carbon dioxide and one volume of water vapor. Experiment has proved it best to supply the proportion of one volume of acetylene to one volume of oxygen through the torch and to require the flame to obtain the additional one and one-half volumes of oxygen necessary to complete the combustion from the air surrounding the flame at the tip of the torch.

The one to one mixture of oxygen and acetylene passing through the torch is not rich enough in oxygen to burn completely the acetylene to carbon-dioxide and water vapor. For this reason it produces two volumes of carbon-monoxide and one volume of hydrogen. This reaction produces the luminous inner cone of the flame which is called the neutral flame.

There is an outer flame, however, called the envelope. This outer envelope is the result of the combustion of two volumes of carbon-monoxide and one volume of hydrogen and the oxygen drawn from the surrounding air.

The carbon-monoxide and hydrogen combine with the oxygen of the surrounding air and burn, the two volumes of carbon-monoxide combining with one volume of oxygen from the air and producing two volumes of carbon-dioxide and the one volume of hydrogen combining with one-half volume of oxygen from the air and producing one volume of water vapor.

The Flame Envelope Is Non-Oxidizing

The envelope formed in this manner consists of non-oxidizing gases which, when in contact with the molten metal, surround the weld with an

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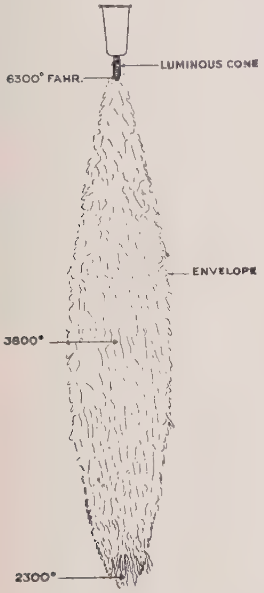
**Some metals conduct or draw the heat away from the point being heated with the torch faster than others. For instance, if the heat conductivity, as this characteristic is called, of silver is taken as 1000, then the relation of the various other metals may be expressed approximately as follows:*

Silver	*1000*	*Wrought Iron*	*144*
Copper	*913*	*Cast Iron*	*112*
Gold	*700*	*Steel*	*108*
Aluminum	*486*	*Lead*	*83*

atmosphere of neutral gases preventing the absorption of oxygen or nitrogen from the air. It is interesting to note that when the first combustion of oxygen and acetylene occurs, yielding hydrogen and carbon-monoxide at the tip of the luminous cone, a temperature of about 6,300 degrees Fahrenheit is produced. Then when the

1 volume of acetylene combines with 2½ volumes of oxygen } *and burns to form* { *2 volumes carbon dioxide and 1 volume water vapor*



1 volume of acetylene combines with 1 volume of oxygen and burns to form 2 volumes carbon monoxide and 1 volume of hydrogen

1 volume of hydrogen combines with Oxygen from the air and burns to form 1 volume of water vapor

2 volumes of carbon monoxide combine with Oxygen from the air and burn to form 2 volumes carbon dioxide

Figure 5—Sketch Showing the Luminous Cone and the Envelope of Flame Produced by a Torch. The Chemical Reactions of the Flame and the Great Variation in the Temperature Developed in the Envelope Are Indicated.

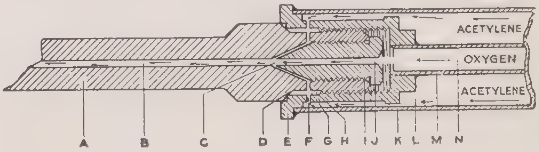
hydrogen burns and forms water vapor, the temperature is about 3,800 degrees, and when the carbon-monoxide changes to carbon-dioxide the temperature is further reduced to about 2,300 degrees. In this remarkable flame, therefore, may be found a range of temperatures from about 6,300 degrees Fahrenheit at the tip of the luminous cone to about 2,300 degrees Fahrenheit at the end of the envelope.

This description will indicate some of the advantages of the oxy-acetylene flame and will show why it is so necessary to design carefully a torch so that equal volumes of oxygen and acetylene will be delivered through it. It will also indicate the necessity for having both gases under the accurate control of the operator so that he can and will adjust the flame and maintain it in this neutral condition.

How the Torch Is Constructed

Figure No. 6, shows a sectional view of a part of the handle and the mixing section which includes what is commonly known as the mixing chamber. Oxygen passes in the direction of the arrows through the center tube and acetylene passes within the handle surrounding this center tube through the ports H and down the conical opening until the point of mixture of the two gases indicated by C is reached. This is an annular orifice, surrounding the main port B which is made by the conical nozzle I. Oxygen passes through the port J, in the nozzle, and meets the acetylene at C. The mixed gases pass together through the port, B, towards the tip. It is obvious that if the areas of port J through the nozzle I and the annular opening through which the acetylene passes at C, are equal, and if the pressures of the two gases, as they are delivered through these ports are equal, equal volumes of oxygen and acetylene will be delivered into the main port B.

This is the object of every well designed torch, and is a basic principle upon which all torches are now constructed. It is true that some torch designers prefer to deliver the oxygen through the mixing chamber at higher pressures through smaller ports and that in some torches the acetylene is delivered through smaller ports at higher pressures. There is also quite a variation in the detailed designs of the mixing chambers and the approaching ports in various makes of torches. In every case, however, the ultimate object of the designer has been to deliver equal volumes of oxygen and acetylene through the torch to the tip, because these proportions produce the hottest, luminous cone of flame and complete combustion when the balance of the oxygen is taken from the air surrounding the flame.



Nomenclature

A—Brass mixing section
B—Mixed gas port
C—Point where gases mix
D—Brass seat of tip assembly
E—Head of torch handle
F—Acetylene port in head
G—Annular passage
H—Acetylene port in mixing section
I—Mixing nozzle
J—Oxygen port in nozzle
K—Acetylene or outer tube
L—Acetylene passage
M—Oxygen or inner tube
N—Oxygen passage

Figure 6—Sectional View Through the Mixing Section and the Head of the Torch Handle of An Equal Pressure Torch Showing the Mixing Chamber.

The mixing section A, Figure No. 6, screws into the torch head E, and can usually be made gas tight by hand pressure without the use of a wrench. This can be done if the seat, D, is in good condition. It is important with this torch, as well as with all others, that the operator appreciate the value of gas tight seats and take proper pains with the mixing section and head to prevent nicking or denting of the seat which will cause it to leak. These remarks also apply to the thread on the mixing section. There is no reason why threads and seats on torches should not be taken care of just as well as any other accurately made removable joint in any piece of apparatus. There is little excuse for the welder who throws a torch tip or handle into a tool box, together with wrenches, hammers and other rough tools and perhaps some old pieces of iron or other metal or equipment. A cap (Fig. 8) is provided for the threads of the mixing section and when the section is changed this cap should be placed upon it before it is laid away. Torches do not make good hammers or pry-bars, and should not be used as such. Rough use simply means the early destruction of the torch involving unnecessary expense.

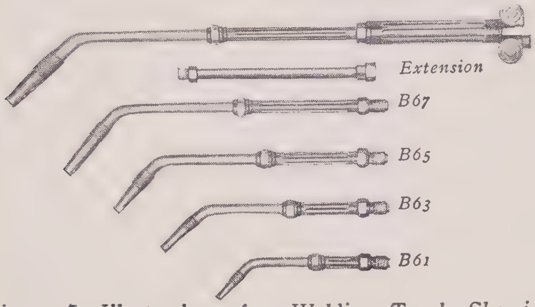


Figure 7—Illustration of a Welding Torch Showing Five Sizes of Tips for Various Thicknesses of Metal and An Extension to Make the Torch Longer When Used Upon Very Heavy Welding.

The Tip Ports Should Be Kept Clean

It is obvious that all of the ports through a torch are proportioned in relation to each other to deliver equal volumes of both gases to the tip of the torch. It is, therefore, essential that none of these ports be reamed out or enlarged in size with wire or other tools, because if this is done the proportions will change and the tips will cease to properly function. In all likelihood, such practice will make the tips back-fire, and a back-firing tip is a constant annoyance to an operator. This does not mean, however, that the port through the end of the tip should not be kept clean and free from accumulations of slag. As welding progresses, small particles of slag are bound to fly from the molten puddle and lodge on the end of the tip. These will sometimes partially obstruct the port through the tip and cause the flame to become irregular, dwarfed in size and finally result in "popping" or back-firing. Sometimes the operator can brush these particles away from the tip end with his glove after the flame has been turned out, but it may become necessary to clean out the hole in the end of the tip. For this purpose tip cleaners are usually supplied with torches to enable the operator to clean the tip properly without enlarging the diameter of the hole. These tip cleaners (Fig. 9) consist of a drill of the proper size for the hole, soldered in a small piece of hexagonal rod to serve as a handle. They are marked indicating the size of tip for which they are intended and the operator should always be sure that he selects the correct size of cleaner for the tip which he wishes to clean.

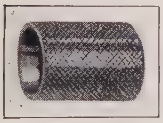


Figure 8—Protecting Cap Used to Prevent the Thread of the Mixing Section From Becoming Burred or Nicked.

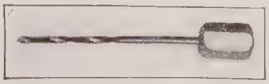


Figure 9—A Tip Cleaner Made of a Drill of the Correct Size Soldered to a Small Piece of Hexagonal Brass.

A beginner will find that from time to time he will accidentally dip the tip end in the hot metal, or keep it too close to the puddle and in this way accumulate upon its end enough slag to interfere with its operation. Judicious use of tip cleaners is always helpful.

Angle of Tip

Preference is sometimes shown by welders for tips which are bent at different angles. Some welders have been taught to use tips having the end pointing at an angle of 45 degrees, while others prefer a tip bent to an angle of 75 degrees. For certain classes of work, a tip may be more useful if bent to an angle of 90 degrees. Some types of torches are made with forged or cast heads, and short tips which screw into these heads. When torches are made in this manner the angle of the tip cannot be changed and for this reason torches are furnished with heads at various angles. Where the tip is made, as illus-

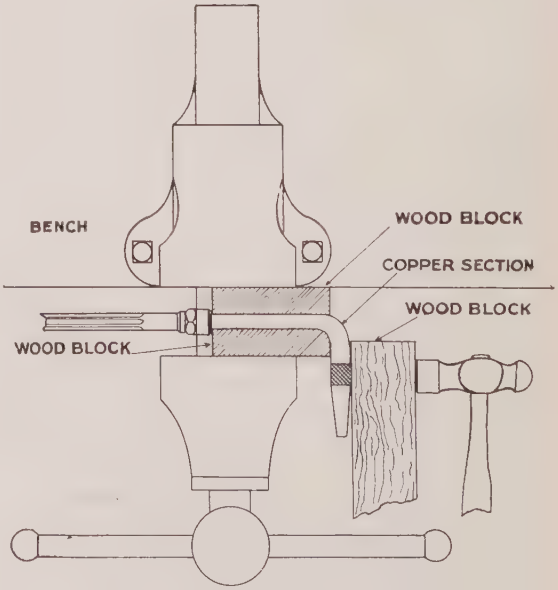


Figure 10—Sketch Showing Method Recommended for Bending Copper Tip Sections.

trated in these lessons, however, it is usually supplied by the manufacturer bent to an angle of 45 degrees. When it is desired to increase this angle, it may be done very simply, as indicated in figure No. 10 and described herewith.

1. Procure three blocks of soft wood, two of them short enough to fit between the nut on the copper section and the bend. The third block must be sufficiently large to strike with a hammer.

2. Place one of the smaller blocks on each side of the copper section, as shown in Figure No. 10, and grip the blocks in a vise, allowing them to extend past the side of the vise about one inch. Tighten the vise sufficiently to imbed the copper section slightly in the wood.

3. Hold the third block of wood against the tip end as near to the bend as possible and strike the block with a hammer. The blows may continue until the desired angle, or a maximum of 90 degrees is reached. As the copper section bends, the metal forces itself into the wood, thus producing a smooth curve without making a sharp, angular bend and without flattening the main port through the tip.

If the copper tip section is merely gripped in a vise without the wood blocks and the tip hammered around the sharp edge of the vise jaw, the bend becomes too sharp and the passage through the tip is likely to be restricted. The usual result of such restriction is back-firing of the torch.

Regulators

The operator will appreciate that despite the fact that he can control the flow of oxygen and acetylene through the torch with the torch valves, it is essential to enable him to do good work, that the gases be delivered to the torch under pressures which fluctuate as little as possible. If the pressures varied, constant manipulation of the torch valves would be necessary to maintain the correct proportion of the two gases and such manipulation would seriously interfere with the work which he has to do.

For this reason, it is essential that good regulators be provided with welding equipment. As described in Lesson No. 1, the pressure within an oxygen cylinder is 2,000 pounds per square inch when the cylinder is full. The pressure within an acetylene cylinder, when the cylinder is full, is approximately 250 pounds. The pressure within a pipe line from an acetylene generator, under normal working conditions, is about twelve pounds. All of these pressures must be reduced when the gas reaches the torch to suitable pressures for the tip in use. These pressures are given in Chart No. 4 and are approximately those at which each tip will operate to produce the average welding flame. In order to reduce these high pressures in cylinders to the lower pressures required at the torch, and to maintain the pressures so that there is as little fluctuation as possible, regulators must be carefully and accurately constructed from a good design.

The principle of most regulators upon the market is the same. They consist of a nozzle through which the high pressure gas passes, a seat to close off the nozzle, like a valve, a diaphragm and balancing springs. These are all enclosed in a proper housing with pressure gauges to show the pressure within the cylinder and the pressure at the outlet of the regulator.

Figure No. 11 shows a sectional view of such a regulator which operates as follows.

Operation of Regulators

The regulator nut and the inlet tailpiece are attached to the oxygen cylinder valve. The adjusting screw is unscrewed or released and the cylinder valve upon the oxygen cylinder opened. Oxygen passes through the inlet tailpiece into the passage through the body and into the nozzle. It is stopped by the seat because the seat is closed. The adjusting screw is then turned to the right transmitting pressure upon the adjusting spring. This presses down upon the diaphragm which in turn presses upon the rocker disc and overcomes the pressure upon the spacing springs. The ball guide assembly, which contains the seat retainer and the seat, is forced downward, thus opening the passage through the nozzle and allowing the oxygen to escape into the low pressure chamber of the regulator. The gas passes through this low pressure chamber and outward through the outlet passage to the outlet nipple of the regulator and through the hose to the torch.

As the oxygen orifice through the torch is small and the flow thus restricted, it will require a certain set pressure within the low pressure chamber of the regulator to continue to force oxygen through the torch. This pressure will show upon the outlet pressure gauge of the regulator which will vary in accordance with the position of the adjusting screw. If the adjusting screw is turned to the right, it will exert more pressure upon the adjusting spring and the pressure of the oxygen upon the outlet pressure gauge will increase. If, on the other hand, the adjusting screw is turned to the left, this pressure will correspondingly decrease.

The ball guide assembly and seat can move freely backward and forward within the body, governed and controlled, of course, by the spacing springs which pull the seat to a closed position and by the adjusting spring which forces it to an open position. As these springs are acting against each other, the position of the seat will depend upon the pressure of the gas within the low pressure chamber of the regulator, pressing upward upon the diaphragm. If this pressure increases because of the shutting off of the torch valve, the pressure on the diaphragm will increase, overcoming the pressure upon the adjusting spring and permitting the spacing springs to close the seat against the nozzle.

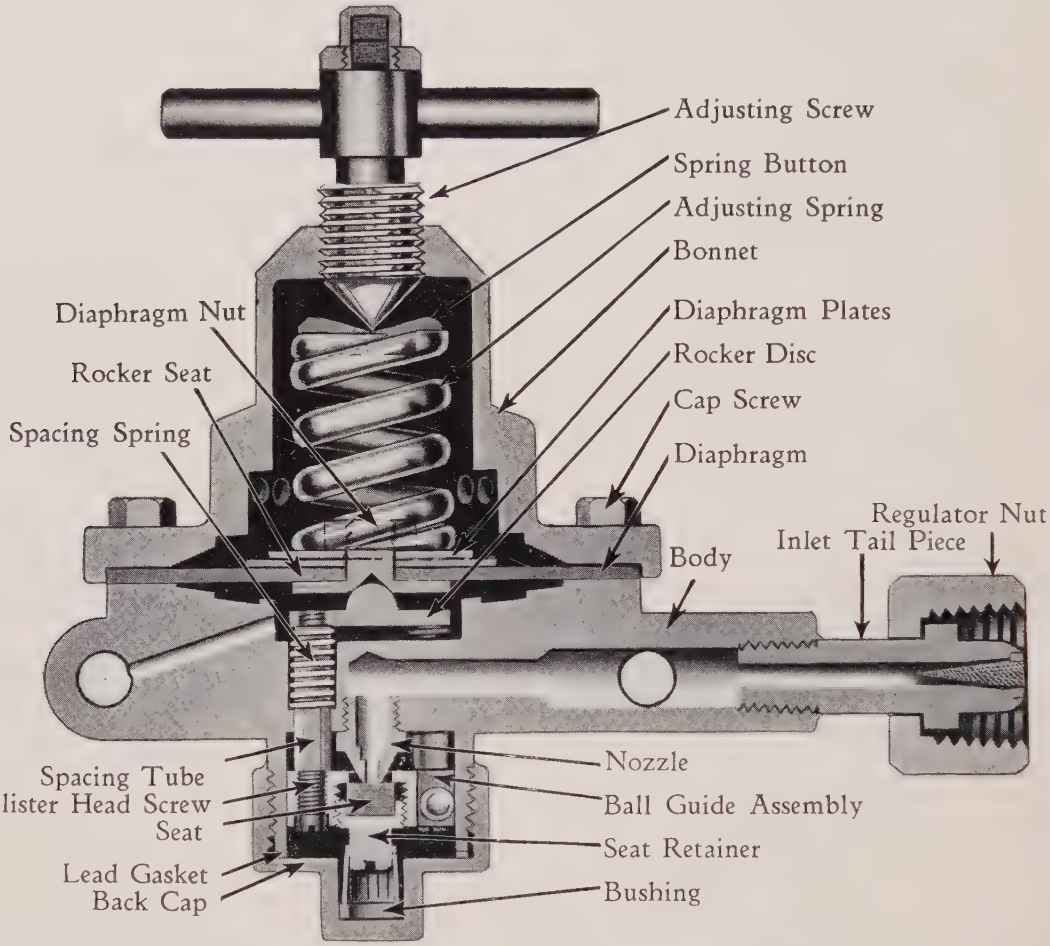

Adjusting Screw
Spring Button
Adjusting Spring
Bonnet
Diaphragm Nut
Diaphragm Plates
Rocker Disc
Rocker Seat
Cap Screw
Spacing Spring
Diaphragm
Regulator Nut
Inlet Tail Piece
Body
Nozzle
Spacing Tube
Fillister Head Screw
Ball Guide Assembly
Seat
Seat Retainer
Lead Gasket
Back Cap
Bushing

Figure 11—Sectional View of An Oxygen Regulator Showing the Nozzle, Seat and Other Internal Parts.

If the pressure within the low pressure chamber of the regulator decreases, because of opening the torch valve, the pressure of the adjusting spring against the diaphragm will overcome the pressure of the gas under the diaphragm and force the spacing springs in a downward position, thus permitting the ball guide assembly and the seat to move away from the nozzle and allow more gas to enter the regulator.

It will be appreciated that this operation of the regulator is entirely automatic, depending upon the opening and closing of the torch valve. It will also be appreciated that the pressures of the gas and the springs against the diaphragm are in a perfectly balanced condition when the seat is held slightly away from the nozzle. The movement of the seat is very little, being only a few thousandths of an inch during the normal operation of the regulator. It will also be appreciated that the condition of the seat and the nozzle must be essentially perfect to enable this sensitive piece of apparatus to operate properly. When the seat closes against the nozzle it must close absolutely gas tight, because if it does not do so, the gas will leak past the seat and the pressure within the low pressure chamber of the regulator will increase in spite of any pressure placed upon the seat by the spacing springs. If this occurs the regulator becomes what is known as a “climbing” regulator. When the regulator “climbs” in this manner when the torch valve is closed, the pressure hand of the outlet pressure gauge will continually increase until, finally, if the cylinder valve is not shut off, the Bourdon tube of the outlet pressure gauge will become sprung and damaged and the gauge will be useless.

Reseating a Regulator

A regulator will not normally develop this condition unless the operator carelessly permits dirt or grit to enter the inlet tailpiece and pass with the gas through the nozzle, where it will lodge on the seat, causing abrasion and leakage. Such leakage can be very quickly determined by the action of the outlet pressure gauge and the whole difficulty can be quickly repaired before any permanent damage is done to the gauge. This is known as reseating a regulator and is accomplished by removing the regulator from the cylinder, screwing in the adjusting screw until the seat is forced away from the nozzle, removing the back cap, unscrewing the seat retainer and replacing the seat with a new one or turning the seat over and using the other side if desired. Additional seats are carried in the upper end of the adjusting screw and can be obtained by unscrewing the hexagonal nut in the end of this screw.

If the regulators are properly taken care of, reseating is not often necessary, but if the regulator shows signs of seat leakage, the reseating can be accomplished in a moment or two without special tools or skill. There is no difference in the construction of the acetylene or oxygen welding regulators except as follows: the outlet thread for the hose connection nut of the acetylene regulator is left hand while for the oxygen regulator it is right hand; the gauges differ in graduation and the inlet connections are arranged to fit the different cylinder valves. The acetylene regulator which is attached to a pipe line is constructed in identically the same manner, except that the springs are less stiff, the nozzle is larger and the outlet pressure gauge is graduated up to fifteen pounds per square inch. The special springs are used because of the low pressure upon the acetylene pipe line from the generator which never exceeds fifteen pounds per square inch. The regulator must accurately reduce this pressure to a lower pressure suitable for the tip in use.

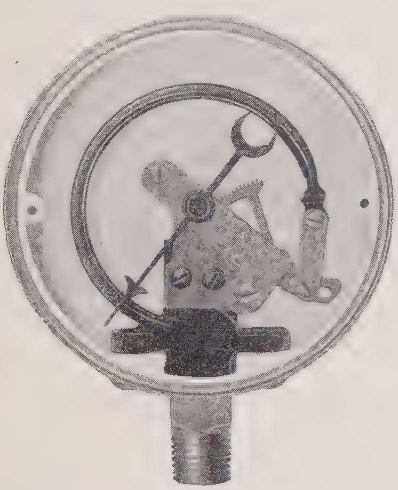


Figure 12—Illustration of an Oxygen Gauge with the Glass and Dial Removed to Show the Bourdon Tube and Mechanism.

Regulator Gauges

The size and graduation of regulator gauges depend upon the make of equipment and vary to a considerable extent. They also vary with the service for which a regulator is to be used. In almost all instances, however, the cylinder pressure gauges of oxygen regulators are similar. The graduations in black figures extend to 3,000 pounds per square inch, although the pressure within the cylinder when full does not exceed 2,000 pounds. These graduations in black figures on the dial show the number of pounds per square inch pressure within the cylinder. On this gauge there is also a smaller scale graduated in red figures. These figures show the number of cubic feet within a standard 220 cubic foot cylinder at 70 degrees Fahrenheit. This means that if the cylinder is inside of a building which is heated to a temperature of 70 degrees the red figures will correctly show the number of cubic feet within the cylinder. If, however, the cylinder is out of doors and the temperature is ten degrees above zero, this scale will not read correctly because cold contracts the gas within the cylinder and the number of cubic feet which will show upon the gauge will be lower than if the cylinder were inside the heated building.

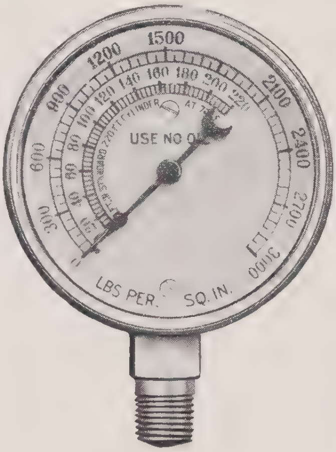


Figure 13—Illustration of a 3,000-pound Oxygen Cylinder Pressure Gauge. This Gauge is Graduated in Pounds Per Square Inch in Black Figures and in Cubic Feet Contained Within the Cylinder in Red Figures.

If the cylinder is full and contains 2,000 pounds pressure at 70 degrees Fahrenheit, the pressure will vary with the temperature, as follows: If the temperature were zero, the pressure within this cylinder would be 1,640 pounds; if it were ten degrees above zero, 1,690 pounds; if 50 degrees above zero, 1,890 pounds, and so on until if the temperature were 130 degrees, the pressure would be 2,310 pounds. There is, therefore, a variation of 670 pounds between zero and 130 degrees in the pressure exerted by the oxygen within the cylinder upon every square inch of the cylinder wall, caused entirely by the contraction of the gas when the temperature is below the standard 70 degrees and by the expansion of the gas when the temperature rises above the standard. It is needless to go into this matter further at the present time, because to be clearly understood, it must be given very careful study and for this reason will be thoroughly dealt with in another lesson.

The outlet pressure gauge of an oxygen regulator may be graduated to fifty pounds if the regulator is intended for welding, or to 150 pounds if it is intended to be a combination regulator for welding and cutting. A regulator, on the other hand, which is used for cutting only may have the outlet pressure gauge graduated to 300 pounds or higher.

The outlet pressure gauge of the acetylene regulator is usually graduated up to fifty pounds per square inch, although acetylene in a free state should not be used at a pressure in excess of fifteen pounds per square inch. The cylinder pressure gauge is usually graduated up to 500 pounds per square inch, although the pressure within the cylinder does not normally exceed 250 pounds. The gauge of the acetylene line regulator attached to the end of the pipe line from the generator is normally graduated up to fifteen pounds per square inch. Graduation of regulator gauges will depend entirely upon the manufacturer, as these are usually constructed to meet his requirements.

Hose Connections

For many years manufacturers constructed hose connections for torches and regulators of various diameters and threads to suit their own particular requirements. This meant that a torch of a certain manufacturer could not be attached to the hose connections furnished by some other manufacturer, and if several makes of equipment were used in the same shop, the hose connections were not interchangeable.

Manufacturers, however, recognized that this was not good practice and through trade and other associations, adopted in 1926 standard hose connections for oxy-acetylene torches and regulators which conformed to Standard No. 107 of the National Screw Thread Commission of the Bureau of Standards at Washington, D. C. This specification covered a small size hose connection for small torches and a larger size connection for the usual size torches and regulators. The small size threading for the hose connection is ⅜ inches outside diameter and the threads are twenty-four threads to the inch, left hand for acetylene and other fuel gases, and right hand for oxygen. The standard threading for the hose connection of the usual size torches and regulators is $\frac{9}{16}$ inches outside diameter and the threading is eighteen threads per inch, left hand for acetylene and other fuel gases, and right hand for oxygen.

The great majority of the manufacturers of welding and cutting equipment in the United States adopted this standard at that time and have since been making hose connections in accordance with these specifications. Therefore, almost all hose connections manufactured since that year are interchangeable. There are, of course, many of the older hose connections still in existence and when these must be used, adapters are necessary to allow the use of the new standard connections.

Notes on Welding Steel

There are certain facts about the welding of steel and about steel itself which the student should know as he continues his study of this subject. These notes are set forth in this lesson, because it includes the first work done upon steel, and knowledge of this metal and its action will be of assistance.

A neutral flame is absolutely essential in welding steel.

Steel is not covered with a protecting scum of oxide when melted and the molten metal oxidizes or carbonizes rapidly when oxygen or acetylene are respectively brought in contact with it.

The hotter the steel in the molten puddle, the faster the chemical reaction takes place.

Too large a flame overheats it and the metal will spark and burn.

The puddle should be closely watched to recognize chemical changes which may take place in the metal.

Mild steel melts at about 2660 degrees Fahrenheit, depending to a considerable extent upon the amount of carbon it contains.

The oxide of steel will melt at a lower temperature than the steel itself.

Flux for dissolving the scale or oxide which forms on molten steel when it contacts with the air is not necessary.

The envelope of the flame should always be kept over the puddle.

Continual removal of the flame from the puddle will cause oxidation, because the hot puddle will absorb or combine with oxygen from the air.

Oxide on solid steel is in the form of a scale which can be easily knocked off the steel with a hammer.

If the flame is allowed to become oxidizing, see Figure C, Chart No. 3, Lesson No. 1, it will cause so much oxide on the surface of the metal that this floating slag will interfere with welding to a serious extent. The oxide melts easily and may be melted into the weld, causing a weak structure.

In welding with adding material, the end of the filler rod should always be melted in the puddle.

Sometimes the welding rod will stick to the edge of the puddle if brought in contact with it. If the rod does stick in this manner, melt it loose with the torch. Accurate control of the welding rod is necessary to prevent sticking and to form a puddle of even width and depth.

Steel will warp when heated. If the heat is applied in the center of a sheet or plate, the metal will be drawn upward or will be forced downward and the plate will bend or warp out of flat.

Steel is ductile and tough and will stretch. The weld and the metal will stretch as it cools and contracts.

The strength of an oxy-acetylene weld depends upon the kind of filler rod used and the workmanship of the operator.

Job Sheet No. 2

Making Corner and Butt Ripple Welds in Sheet Metal One-sixteenth Inch in Thickness

1. The same equipment is required as specified in Job Sheet No. 1, including a tip of the right size for the one-sixteenth inch steel as shown by the manufacturer's chart. A tip of the same size as the No. 1 is correct. There should be a plentiful supply of pieces of sheet steel one-sixteenth inch in thickness, one inch in width and six inches in length.
2. Open the valves of the cylinders, set the regulators to the correct pressures and light the torch as described in Job Sheet No. 1.
3. Close the torch valves and hang up the torch temporarily until pieces of sheet steel are set up ready to be welded.
4. Select two pieces of sheet steel and set them across the fire bricks at right angles to each other, in appearance like an inverted V, as shown in Fig. No. 1.
5. Light the torch and adjust the torch valves until a neutral flame is produced. Hold the flame near the edges of the metal at the right hand end of the plates until these edges become fused, then draw the torch away for a moment, allowing the fused metal to run together, thus making a tack weld.
6. Make a similar tack weld at the left hand end of the two plates. If it is found difficult to make the melted edges of the two pieces of steel flow together in tack welding and they keep melting down and separating further as they melt, a little metal fused to them from the filler rod will make the molten edges flow together. The object of this lesson, however, is to make the weld without the addition of more metal unless necessary in making the first tack welds, or if a hole should be burned in the plate accidentally.
7. Hold the torch with the luminous cone of flame about one-sixteenth of an inch away from the edges of the metal at the right hand end until the edges and the tack weld are fused, thus making a molten puddle of metal. Hold the torch in the position shown in Fig. No. 1 and move it slowly along the seam, at the same time giving it a slow, cross-wise motion as it progresses forward. This cross-wise motion is intended only to assist in making the molten puddle bridge what little gap there may be between the sheets. The sheets should be, of course, as close together as possible at the top edges. The torch must not be moved too rapidly along the seam or the puddle will not melt clear through the metal. Penetration of the weld clear through the seam to the bottom edge is one of the most important requirements of welding. A skin weld just coating over the surface has no strength and is really worse than no weld at all, because its surface appearance indicates a good weld, while in reality it has little depth and, therefore, little strength.
   On the other hand, if the torch is moved too slowly along the seam the puddle may become so hot that the molten metal will drop through the seam and leave a hole. If this occurs, use a little filling rod in building up the metal at the edges of the hole until it is completely closed over. When the hole is closed continue the seam as before until the edges of the two sheets have been completely welded. Do not go back over work already welded. The flame is hot and the second time it is moved over a weld which has already been made it will burn the metal more or less.
8. Shut off the torch temporarily and select two more pieces of the sheet steel and set them across the bricks in the form of an inverted V as shown in Fig. No. 1.
9. Light the torch and adjust the flame until it is neutral.
10. Tack weld the edges of the metal at each end as heretofore described.
11. Make a similar weld between the edges of the two pieces of steel as heretofore described, but move the torch forward along the seam at an even speed without the cross motion. In other words, keep the torch progressing steadily along the seam advancing the puddle before it and note whether the cross motion assists in making the weld or causes any change in the ripple formation.
12. Select two more pieces of steel and place them flat across the bricks with their edges in contact, as shown in Fig. No. 2.
13. Tack weld the two pieces at each end of the seam as indicated.
14. Melt a puddle at the right hand tack weld and move the torch evenly along the seam advancing the puddle with the forward movement of the torch, but do not use a cross motion.
15. Continue the forward movement of the torch, keeping the puddle round and flowing freely until the end of the seam is reached. The result will be a butt weld between two pieces of sheet steel made without filling material.
16. Continue making corner and butt welds until the molten metal can be accurately controlled and the seam made with a reasonable degree of smoothness. Compare the result with Figs. Nos. 3 and 4. Photograph No. 3

was made as indicated in Fig. No. 1, using a forward and a slow cross-wise motion of the torch. The weld shown in Fig. No. 4 is a ripple butt weld made as indicated in Fig. No. 2. This weld was made by moving the torch along the seam in the forward direction, but without any cross motion. The cross motion may be found advantageous when making the corner weld, but is unnecessary in making the butt weld.

Do Not Become Discouraged

Welding is the result of skillful manipulation of the torch. It appears to be very easy and in reality is easy, but it requires sufficient practice to gain the necessary skill to control the metal properly. Control of the metal is the result of heating the piece being welded to the point of fusion, melting the welding rod in the puddle and holding the torch in such manner that the metal will not become too hot and run away, and on the other hand, will not become so cold that the welding rod sticks to the edge of the puddle or the puddle itself solidifies. The temperature must be maintained just hot enough to keep the puddle in a flowing condition and maintain it evenly and regularly along the seam. The beginner should not become discouraged, because he cannot immediately acquire the necessary skill. Practice is essential and patient application of the instructions given in this lesson will result in the course of a few hours in very fair welds.

Caution:

Never use oil or grease to lubricate oxygen cylinder valves, oxygen regulators, torches or any other welding and cutting apparatus. There is one exception to this rule and only one and that is acetylene generators. Generators must be kept oiled to operate properly.

Questions:

1. From which side (right or left) should the ripple weld be commenced?
2. What causes the formation of the "ripples"? Is the motion of the torch responsible for the formation of a ripple weld?
3. Describe the methods of making a ripple weld.
4. What type of adding material should be used in tacking the metal together, filling up a hole, or building up a low spot?
5. Can any size of tip assembly be used in this lesson? Why?
6. Will the same tip that is used for welding a steel rim ½ inch thick and two inches wide weighing fifty pounds be satisfactory for welding a steel block of the same weight three inches thick and two inches wide?
7. What is the chemical reaction that occurs within the luminous cone?
8. Why is it advantageous to allow the envelope of the flame to surround the weld as it is being made?
9. Where is the hottest part of the flame?
10. What is the range of temperatures found within the limits of the flame?
11. What is the basic principle upon which all properly designed welding torches are built?
12. What is a guard cap; a tip cleaner? What are their purposes?
13. Describe the proper manner in which the angle of a tip assembly illustrated in this lesson should be altered. What is the reason for using this method?
14. What is the purpose of a regulator?
15. Describe the operation of a regulator?
16. What is a climbing regulator? What happens if the regulator is not reseated?
17. What is the procedure for replacing a regulator seat?
18. Describe the four gauges upon a set of regulators and tell the purpose of each. What do the graduations indicate?
19. What are the differences between an oxygen regulator and an acetylene regulator?
20. Is there any difference in the pressures of two oxygen cylinders containing the same amount of gas, one in a building with a temperature of 70 degrees Fahr., the other out of doors where the temperature is zero? What is the reason?

Lesson No. 3

Welding Sheet Steel

Oxygen Acetylene and Cylinders

WELDING steel sheets or plates greater in thickness than one-sixteenth of an inch usually requires the use of adding material, or what is commonly called a welding rod. In Lesson No. 2, the student learned to weld two pieces of No. 16 gauge sheet steel without the use of welding rod, except for tacking or in case a hole was melted through the sheet. The next step in learning to weld is the application of the welding rod continuously in conjunction with the torch to make a seam between two pieces of steel. For the practice work in this lesson steel one-eighth inch in thickness has been selected. A tip the size of the No. 2, and welding rod three-thirty-seconds inches in diameter should be used.

These welding rods should be of the same specifications given in Lesson No. 2 on page 14, namely, a low carbon steel, in general, meeting the requirements of the American Welding Society's specification G-No. 1A. The edges of these steel plates are not bevelled or veed, but are straight edges as illustrated in the second sketch from the top of Chart No. 4, Lesson No. 2. The two pieces of plate are placed with the edges close together, but not actually touching. A slight space is necessary between the edges so that the weld may penetrate to the bottom of the sheet.

A good deal of practice work will be necessary to accomplish this weld and it will be desirable for the student to obtain some scrap pieces of sheet steel, or any scrap steel one-eighth inch in thickness. This practice work is generally called beading practice and the flat surface of the scrap steel will serve the purpose. It is not necessary that the practice work should be carried on directly over a seam in two pieces of sheet steel, but a number of beads can be run side by side on the flat surface. If steel sheets greater in thickness than one-eighth inch are used, then it becomes necessary to use a larger tip and a larger welding rod, which consumes more steel, more oxygen and acetylene and hence costs more money. The one-eighth inch steel, the No. 2 tip or its equivalent, and three-thirty-seconds inch welding rod will answer every purpose for this practice and enable the student to develop the necessary skill in handling both the welding rod and the torch.

There are many different ways of accomplishing the same result in welding a bead upon a piece of steel. Some skilled welders will take the torch in the left hand and the welding rod in the right hand and by manipulation of both produce an excellent bead. Other welders will take the torch in the right hand and the welding rod in the left hand and likewise produce excellent results. Some welders prefer to weld from left to right, while others prefer to weld from right to left. These various methods and the under-lying reasons for them have been given very careful consideration in planning this lesson and it is believed that the method described will be found to be very efficient and one which can be quickly mastered by the average man.

Semi-Circular Movement Method

This method has been called the semi-circular movement method, because the torch moves in progressive semi-circles along the line of weld. The rod on the other hand is moved straight back and forth, to and from the welder, but alternating with the movement of the torch. The reasons for this method are based upon sound principles, and there is as little waste motion as possible in the movement of both torch and rod.

This method is illustrated in Figs. 1, 2 and 3. The torch is held in the right hand and the welding rod in the left hand and the welder stands fully erect in front of the welding table. When the operator stands, as illustrated in the three sketches, and holds the torch as shown in the right hand, the torch can easily be moved in small semi-circles not quite the width of the bead, each semi-circle progressing slightly forward from right to left. In the beading practice in question, the width of the bead should not exceed three-eighths of an inch and this should be slightly more than the diameters of the semi-circles.

The manner in which the torch is held in the right hand will depend somewhat upon the angle of the tip. If the angle is 45 degrees, as is the case with the torch illustrated, it will be held as shown. If the angle is 75 degrees or 90 degrees, the position would be changed somewhat to enable the welder to hold the torch comfortably and in a well balanced position. It is important that the welder stand up straight, that he hold the torch in his right hand and the welding rod in his left hand if he is a right handed man. In this event the weld will progress from right to left. If on the other hand, he is a left handed operator, he can accomplish the same results by holding the torch in his left hand and the welding rod in his right hand and in this event the weld will progress from left to right.

The student should stand in front of the table with the torch in position, as shown in Fig. 1, and practice this movement of the torch without the flame lighted until his muscles become somewhat accustomed to it, and he can easily move the torch in this manner. The welding rod should be bent to a right angle as indicated in the sketches, because the bent rod can be more easily manipulated in the proper position with relation to the flame than a straight rod in this method of welding. The rod is moved directly backward and forward across the line of the weld, the movement to be not quite so wide as the puddle. This movement of the rod alternates with the movement of the torch. In other words, when the torch is furthest away from the welder the rod is nearest the welder, and when the rod is nearest the welder the torch is furthest away. This slow, alternate movement of the rod and torch, the rod straight across and the torch in semi-circles, continues along the line of the seam as the weld progresses.

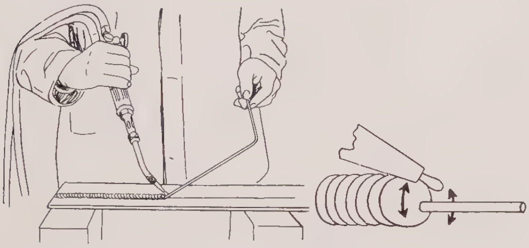


Figure 1—This is a Sketch Showing the Semi-Circular Movement of the Torch in Making a Weld with Filler Rod. The Torch is on the Opposite Side of the Rod from the Reader. From this Position the Torch is Moved in a Semi-Circle Behind the Rod and the Rod is Moved Across the Weld to the Opposite Side. The Middle Position of Both Rod and Torch are Shown in Figure No. 2.

The swinging motion of the torch around the puddle will, if properly done, keep the welding rod from sticking to the edges of the puddle. The welding rod should always be moved in the molten metal.

The rate of progress along the seam should be just enough to assure complete fusion of the steel and at the same time enable the operator to leave behind the puddle an even, regular ripple weld.

This rate will increase as the operator acquires more skill in handling the torch.

Movements Are Made With Definite Purposes

It should be clearly understood by the welder that one of the most important objects of the movement of the torch is to assure full penetration of the heat to melt the metal clear through to the bottom of the seam. Another object is to prevent the luminous cone of the flame from actually licking the rod or the molten metal in the puddle. A further object is to hold the rod in such manner that it will to a certain extent, block the heat to prevent overheating of the edges of the metal beyond the puddle.

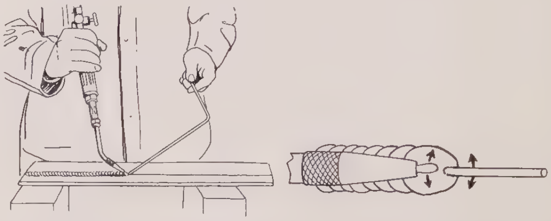


Figure 2—In this Sketch the Torch is Directly in Line with the Rod and the Rod is Blocking the Puddle. This is the Middle Position of the Movement of Both Torch and Rod.

In the forward movement of the torch at each extremity of the semi-circle the flame is directed down into the crack to heat the metal forward of the rod clear through the seam. It then passes back of the rod, care being taken that the luminous cone of flame does not come in contact with the rod and completes the semi-circle to the opposite side of the seam where it is again directed forward to heat the metal beyond the rod and the puddle. A circular puddle is thus produced with the rod in its center.

Method Good for Lighter Steel

This method of welding is advantageous, particularly for the thinner sections of metal. When the metal is heavy and the edges are bevelled, it may be found advantageous to weld from left to right, in which case the movement of both the torch and the rod differ from that described. In welding heavy castings an entirely different movement of both torch and rod may be necessary. The method of welding differs considerably with the work being accomplished. The broad principles, however, of the semi-circular movement method apply in most instances.

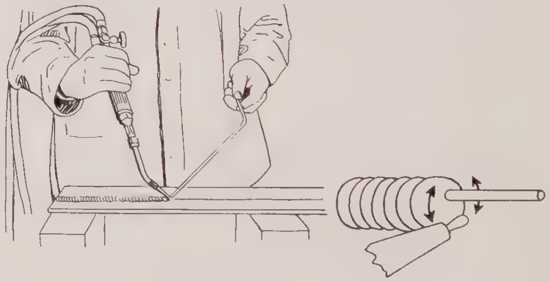


Figure 3—In this Sketch the Torch is at the Opposite End of the Semi-Circle and is Nearest the Reader. The Rod Has Been Moved to the Opposite Side of the Weld. The Movement of the Torch is, Therefore, in Semi-Circles Alternating with a Straight Backward and Forward Movement of the Rod. This Movement of the Torch and Rod May Well be Called the Semi-Circular Movement Method of Welding.

These principles are important and are repeated so that the student will be sure to remember them.

The maintenance of a puddle of molten metal which progresses evenly down the seam, as the weld is made.

The melting of the rod in the puddle.

The prevention of the luminous cone of flame from coming in contact with the rod or the molten metal of the puddle.

The forcing of the flame ahead of the puddle, without interference with the rod, to heat the metal in advance of the puddle.

Last, but most important of all, the penetration of the molten weld clear to the bottom surface of the sheet or plate being welded, without allowing the molten metal to drip in beads from the bottom of the weld.

It all resolves itself into a problem demanding sufficient knowledge of the heat which is being applied to enable the operator to control the metal, and enough manual skill to manipulate both torch and rod regularly and easily along the seam.

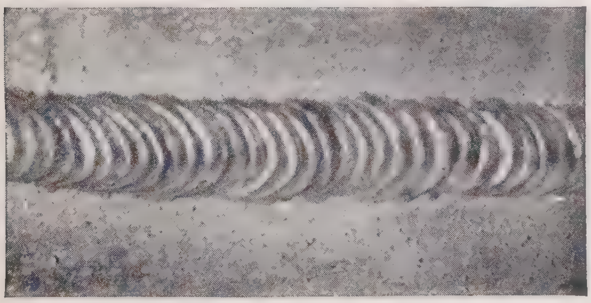


Figure 4—Photograph of a Weld Made by the Semi-Circular Movement Method. This Method is Easy to Learn and Produces a Strong, Sound Weld, Free from Inclusions of Slag and Blow Holes. It Also Assures Full Penetration to the Bottom of the Joint.

It will not be attempted in this lesson to describe any other method of welding. It is believed to be far better for the student that he master this one method before attempting to weld in other ways. When he can make a smooth uniform bead upon a piece of steel and can weld the two edges of the sheets together, making a good weld, it will be time enough to consider other methods of welding.

Oxygen

Oxygen is a very common element. The oceans, covering approximately three-fourths of the earth's surface, and rivers, lakes, etc., consist of one-third oxygen by volume in the form of water. Air is made up of approximately twenty-one parts of oxygen, seventy-eight parts of nitrogen and one part of such rare gases as argon, neon, etc. The crust of the earth is largely made up of various oxides. Oxygen has a very strong affinity for other materials, such as carbon, hydrogen, many of the metals and some of the earths and for this reason in the early geological ages it combined with other materials making compounds which can be broken up into their elements only with difficulty.

The combination of oxygen and nitrogen in the air is not a chemical one however. Both gases are in a free state, but even so, it is quite difficult to separate them, and it has only been within the last thirty years that commercial oxygen producing plants have been established in the United States.

It was not until 1908 that the first commercial oxygen plant began the production of oxygen in quantity, so that although the calcium carbide method of producing acetylene was discovered in 1892, it was sixteen years later that welding as we now know it was commercially possible.

How Oxygen Is Made

There are two principal processes for the commercial production of oxygen. One of these is the separation of air into oxygen and nitrogen by liquefying the air and the other is the separation of water into oxygen and hydrogen by the electrolysis of water, or in other words, by passing an electric current through it. By far the greater proportion of the oxygen which is consumed in the United States is manufactured from air by the liquefaction process, and for this reason, a short description of this process will be given.

Liquefaction Process

A modern plant for producing oxygen by this process consists of air purifying towers, an air compressor and coolers, a drying battery and filter, a liquefaction column, a gas meter, a gas holder, an oxygen compressor and a cylinder charging manifold. The air is drawn by the air compressor through the air purifying tower where it comes in contact with a caustic solution sprayed over baffling devices. It enters the air compressor where it is compressed, when the equipment is first started, to a pressure of about 3,000 pounds, depending somewhat upon the type of equipment in use, and cooled so that the heat of compression is eliminated. The air then enters the drying battery where moisture and traces of carbon dioxide are removed through absorption by the caustic potash contained in the dryers.

From the dryers it enters the liquefaction column which is the heart of the plant where the oxygen is separated from the nitrogen. The liquefaction column is a tower, well insulated from the outside air. Within this insulated tower is a long vertical copper cylinder enclosing a series of copper coils constituting a heat exchanger. The dry air, free of carbon-dioxide and under a normal working pressure of about 1,000 pounds, passes downward through the spiral tubes which are in contact with rising, cold nitrogen gas, thus lowering the temperature of the air. It continues downward through the coil until finally the coil reaches the lower part of the copper cylinder where it makes several turns submerged in liquid oxygen already produced. The coil then rises to a point about midway in the tower and there the air is expanded through a needle valve from a pressure of 1,000 pounds to approximately five pounds.

It has already delivered heat to the liquid oxygen through which the coil passes, and expansion still further reduces the temperature to a point where the air will liquefy. This liquid trickles down over a series of baffle plates and the separation of oxygen from the nitrogen takes place for the following reasons:

At the pressure within the machine, oxygen will liquefy at approximately 295 degrees Fahrenheit below zero. Nitrogen, on the other hand, will not liquefy until the temperature is 317 degrees below zero. There is, therefore, a difference between the liquefaction temperatures of these two gases of about twenty-two degrees.

Therefore, when the spray of liquid air passes downward from the expansion valve, the nitrogen reverts back to the gaseous form more quickly than the oxygen and as it is lighter, rises to the top of the apparatus whereas the oxygen still in liquid form precipitates to the bottom. The action can be likened to the rising of steam from a teakettle on a stove. Water still remains in the kettle, while the steam rises from it as the water boils. The liquid oxygen collects in a reservoir at the bottom of the column and rises through a set of coils where it is changed to gas form by absorbing heat from the incoming air, circulating in separate coils closely in contact with those containing the oxygen. The oxygen in gas form finally leaves the top of the apparatus, passes through the meter and out to the gas holder. The nitrogen is allowed to escape to the outside air as it is not used under normal conditions. The oxygen compressor draws oxygen from the gas holder and compresses it in oxygen cylinders to a pressure of 2,000 pounds per square inch.

Figure 5—Sectional View of An Oxygen Cylinder. Oxygen Cylinders Are Seamless, Drawn, Steel Vessels, Having a Malleable Iron Neck Ring Shrunk on at the Top and a Cylinder Valve Screwed into the Neck.

Oxygen Cylinders

The usual size oxygen cylinders which will be generally found in welding shops, machine shops, manufacturing plants, etc., where oxygen is used for welding and cutting, contain 220 cubic feet of oxygen measured at atmospheric pressure, or the ordinary pressure of the air outdoors, which is equivalent to 14.7 pounds per square inch at sea level. This cylinder is shown in Fig. 5 and is fifty-five inches in length, nine and one-eighth inches in diameter and weighs, when full, approximately 145 pounds. Cylinders are charged to 2,000 pounds per square inch when full, which is an extremely high pressure. For this reason, cylinders must be manufactured and tested with extreme care under proper specifications. The Inter-State Commerce Commission requires all cylinders containing compressed gases to be constructed and tested and to be periodically tested while in use in accordance with certain rules and regulations specified by the Bureau of Explosives in New York City. Cylinders not manufactured and tested in accordance with these rules cannot be shipped on the railroads.

One process for the manufacture of cylinders consists in forcing a heated steel block through a die with a punch or mandrel and in this way forming a cup about one-quarter of the height of a cylinder and larger in diameter. This is called piercing a slug. After passing through two dies, each smaller in diameter, the cup is drawn into the shape of a long, open top steel vessel. Finally the neck or top of this vessel is swaged down to form a small neck, like a bottle, which is threaded on the inside to receive the cylinder valve. The neck ring to hold the cylinder cap is shrunk over the neck. The cylinder is in fact a seamless drawn steel bottle.

The internal capacity, or the amount of water which it would hold, if filled, is maintained as nearly as possible between 2,600 and 2,700 cubic inches and is ordinarily figured to be 1.528 cubic feet. As oxygen is compressed it will, of course, occupy very much less space than it does in the free state when not under pressure. As it is compressed into the cylinder, it is squeezed into this small space and when the cylinder is full, it has been compressed in volume slightly more than 143 times. The cylinder is, therefore, an economical means for transportation.

As stated in Lesson No. 2, oxygen, like other gases, expands and contracts when subjected to heat or cold. This expansion or contraction causes increased or decreased pressure upon the interior walls of the cylinder as the gas is striving to occupy more or less space.

The Bureau of Standards at Washington, D. C., has developed some very useful figures upon the contents of oxygen cylinders under varying conditions of pressure and temperature and these are expressed by an approximate chart, reproduced upon page 29 as Chart No. 5, which is very easy to use and gives figures accurate enough for all ordinary purposes. The chart looks complicated, but should not be considered as such. The explanation in the caption is simple and a little study of this explanation will show how the chart is used.

Oxygen Manifolds

When welding and cutting are to be carried on at many points about a shop, or a large manufacturing plant, it often becomes more convenient to install an oxygen cylinder manifold at a location where the cylinders can be easily handled, and to pipe the oxygen in pipe lines throughout the shop. At various points where convenient, outlets are arranged with valves and fittings to which oxygen line regulators may be attached. This provides what are called station outlets which are usually located beside similar acetylene regulators connected to an acetylene line from a generator. In this manner a convenient welding and cutting station is arranged and the hose lines to the torch can be connected to their respective regulators and the process carried on within reach of the hose.

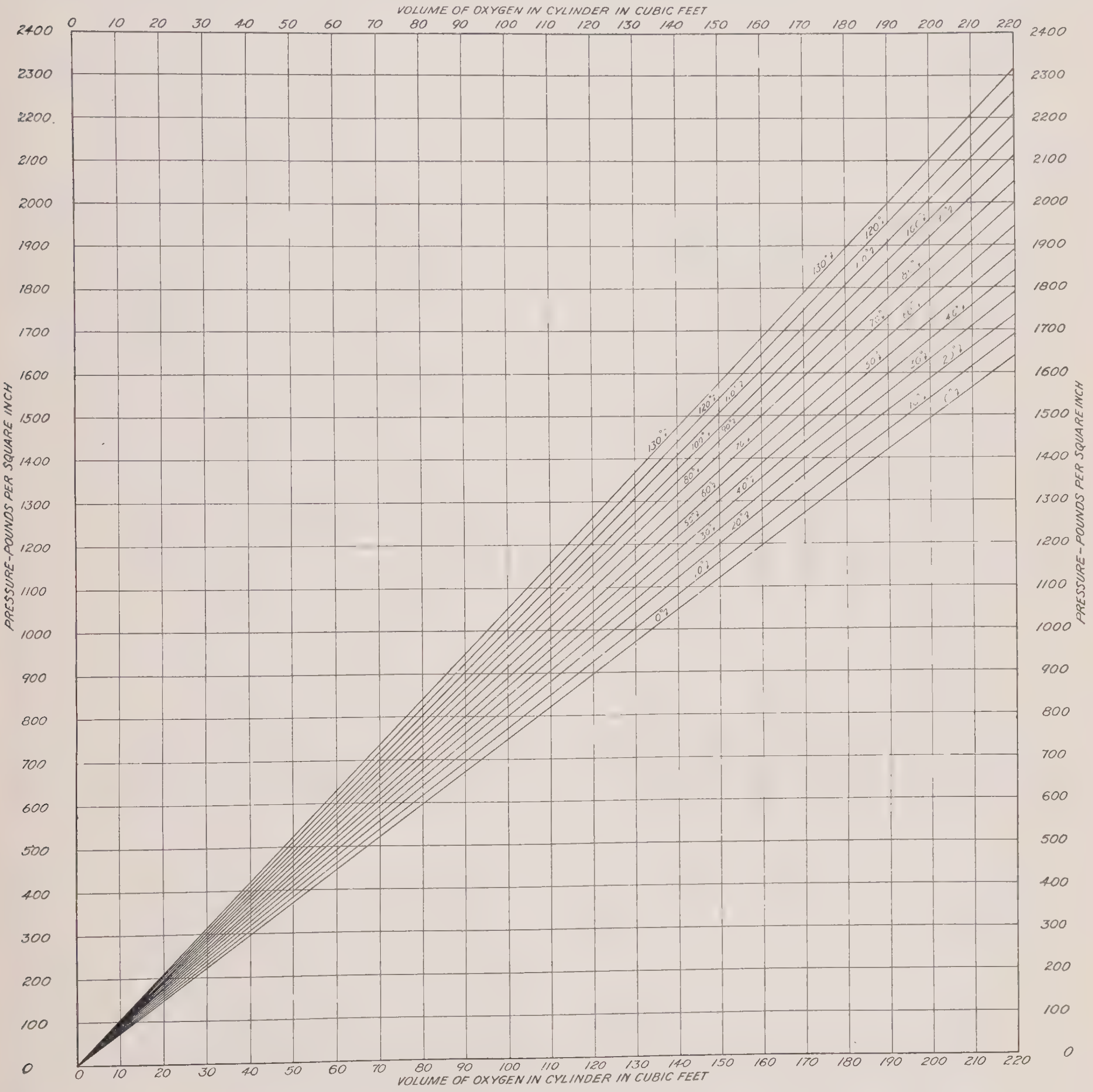


Chart No. 5—This Chart Shows the Approximate Volume of Oxygen in Any Standard 220 Cubic Foot Cylinder of Oxygen at Any Pressure and at Temperatures Ranging from Zero Degrees to 130 Degrees Fahrenheit. Its Use is Very Simple. Example—Suppose for Instance That the Pressure in a 220 Cubic Foot Cylinder, as Shown by the Regulator Pressure Gauge was 1,200 Pounds, and the Temperature was 30 Degrees. How Much Oxygen Would Such a Cylinder Contain? Follow the 1,200 Pound Pressure Line Horizontally Across the Chart Until it Intersects the 30 Degree Diagonal Line. Then Look Vertically to the Bottom of the Chart and Read off 145 Cubic Feet Midway Between the 140 and the 150 Cubic Foot Lines. Each Square Horizontally is Equal to 10 Cubic Feet and Each Square Vertically to 100 Pounds Per Square Inch.

An oxygen manifold to connect six cylinders together, three on each side of the manifold, is shown in Fig. No. 6. The operating pressure within this manifold is 2,000 pounds per square inch, and for this reason the fittings and the pipe of which it is made, together with the valves, must be sufficiently strong to withstand this pressure safely. Ordinary valves and pipe are not strong enough for this purpose. Manifolds are made of extra heavy brass pipe with special fittings and valves manufactured particularly for this purpose. It will be noticed that on this manifold there are outlets for two regulators and that both the outlets of these regulators are connected to the pipe line leading to the various stations about the shop.

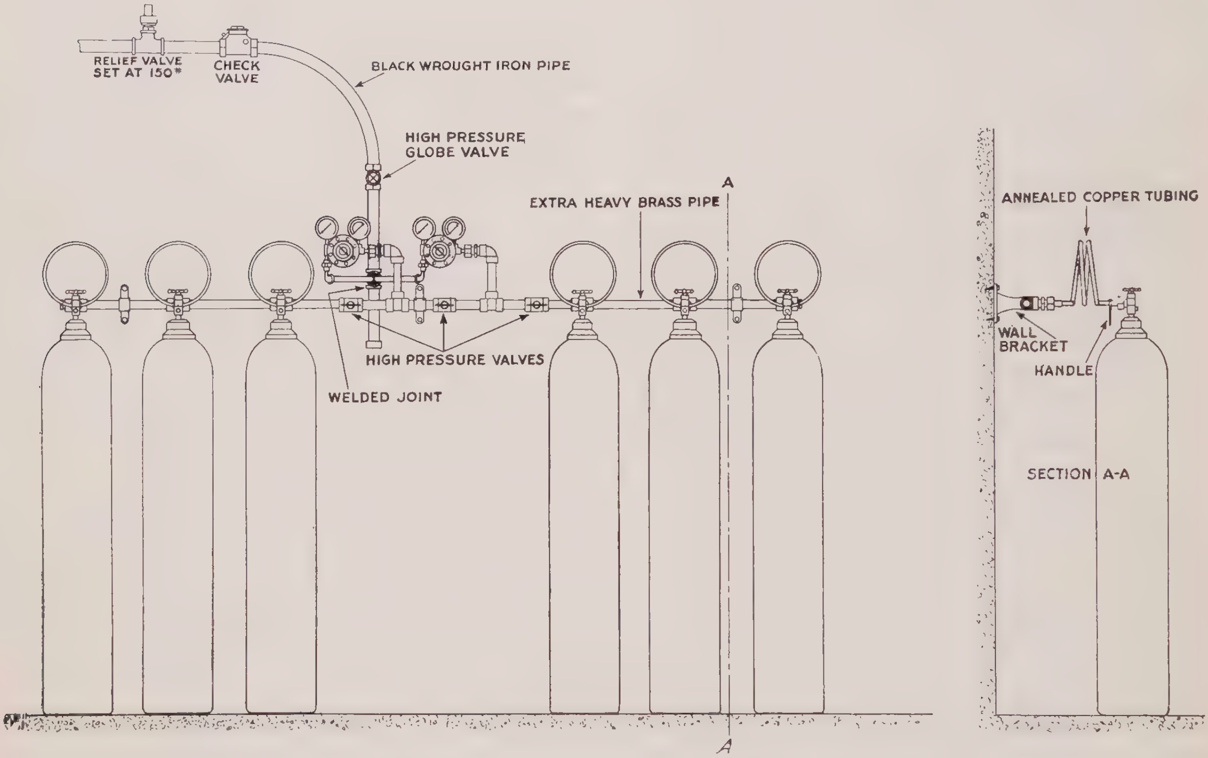


Figure 6—Sketch Showing an Oxygen Manifold. It is Often Very Convenient to Place All of the Oxygen Cylinders at One Point Where They May be Readily Handled and to Connect Them Together to an Oxygen Manifold, as Illustrated. There is the Full Cylinder Pressure of 2,000 pounds Per Square Inch in the Manifold Pipes and This is Reduced by Regulators to a Line Pressure of Fifty or Seventy-five Pounds in the Line to the Various Station Outlets About the Shop.

There is a high pressure valve located between these regulators so that they can be used either individually or both together. Also if one regulator becomes out of order or requires reseating, it may be removed and the gas discharged through the other regulator without shutting down both sides of the manifold. The high pressure valves shutting off each side of the manifold are so arranged that one side of the manifold can be shut off while the other is in use, and the empty cylinders from this side removed and full cylinders substituted therefor.

There is a further function of the three high pressure valves which applies particularly to the larger manifolds and shops where there are a great many welders at work simultaneously. The manifold can be extended to include as many cylinders as is desired and it might easily be large enough to connect ten or even twenty cylinders on each side of the regulators. Suppose, in Fig. No. 6 that the left hand side of the manifold were in operation, the middle and right hand high pressure valves closed and the right hand side of the manifold held in reserve to be turned into the line when necessary. If the line pressure required were fifty pounds, and the left hand cylinders were being rapidly exhausted, there would come a time when there would be, perhaps, one hundred pounds pressure in the left hand cylinders and yet this pressure would be insufficient to maintain the fifty pound line pressure with all of the torches in operation. It would be wasteful of gas to remove the left hand cylinders until as much of the gas as possible was discharged from them.

The arrangement of the high pressure valves is such that under these conditions the following procedure can be utilized to drain the left hand group of cylinders down to the line of pressure. The right hand high pressure valve is opened thus permitting the right hand group of cylinders to discharge through the right hand regulator into the line. As the center high pressure valve is closed, the left hand cylinders will continue to discharge through the left hand regulator until the pressure within the cylinders has been reduced to the line pressure or fifty pounds. A little study of Fig. No. 6 will show how simple this is.

The pipe line from the manifold to the station outlet is usually made of black wrought iron pipe with all joints welded, except those at the relief, check and blow off valves and the valves at the station outlets.

The diameter of the pipe should be sufficiently large to supply ample oxygen for the number of stations in use. Near the manifold a relief valve is shown set at 150 pounds per square inch. This valve will prevent excessive pressure from accumulating in the line because of a faulty or leaking regulator. There is also a check valve in the line to prevent any possibility of acetylene backing into the line when it is not in use. A high pressure globe valve has been provided immediately above the manifold to shut the line off if the regulators are to be removed and a cap at the end of the line to remove an accumulation of moisture.

Oxygen Cylinder Valves

A sectional view of an oxygen cylinder valve is shown in Fig. 7. This is a typical valve having a hard rubber or an alloy metal seat and a fiber disc under the bonnet nut in the upper portion of the valve surrounding the stem. A valve of this type will not ordinarily leak by the stem even though the valve is only partly open.

There is a type of valve upon the market, however, in extensive use which requires that the valve stem be unscrewed to an extreme upward position in order to stop leakage by the stem. This valve has a rubber compression disc, which is compressed by the upward movement of the valve stem and washers until it expands and prevents leakage of the gas by the stem.

A bursting disc, which is held in place by a nut, is shown at the rear of the valve, Fig. 7. The disc is supported in the nut by fusible metal which will melt at approximately 240 degrees Fahrenheit and in this event the disc will burst and release the gas, thus preventing an abnormal pressure from developing in the cylinder in case of a fire. Almost all oxygen cylinder valves have a hand wheel on the stem. Wrenches should not be used to open or close cylinder valves, because of the likelihood of injury to the seat. It may become necessary at times, however, to tap slightly the hand wheel in order to open the valve if it is stiff in its operation.

Care should always be taken to prevent injury to the threads of the outlet nipple. Oxygen cylinder valves in the United States are all standard in so far as the outlet threads and the general shape of the nipple are concerned. This thread is 29/32 inches in outside diameter, has fourteen threads to the inch and is a right hand thread. Regulators are, therefore, generally interchangeable upon oxygen cylinders without the use of adapters.

Calcium Carbide

Calcium carbide was discovered in 1892 by James Turner Morehead and Thomas Leopold Willson at Spray, N. C. These men were engaged in experiments with an electric furnace to produce aluminum. On May 2, 1892 an experiment was conducted in which coal tar and lime were fused in the electric furnace. It was thought that this would produce metallic calcium, but instead of this metal, the product was a crystalline substance which made a gas if placed in water. It was found when this gas was lighted that it gave off a heavy black smoke and the gas was later determined to be acetylene. The crystalline material was calcium carbide now used so extensively to produce acetylene for welding and cutting. The carbide industry grew very slowly at first, as at that time the possibilities of carbide were not realized and there was no developed use for it. It was principally used for laboratory and experimental purposes.

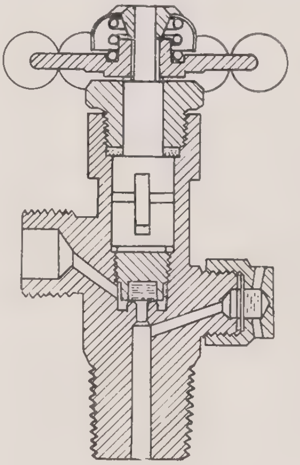


Figure 7—Sectional View of an Oxygen Cylinder Valve. This is a Typical Valve Used Upon Many Oxygen Cylinders.

It was then found that acetylene could be used for lighting purposes and country homes were lighted extensively with it. Methods were also developed for compressing it, dissolved in acetone, into cylinders; the result was the automobile lighting tank which a few years ago was attached to almost every automobile prior to the development of the electric generator and the electric light. Acetylene compressed in cylinders was also used extensively for marine lighting purposes, that is for lighting buoys, lighthouses and similar signal equipment. As the commercial production of oxygen developed, the use of carbide in the manufacture of acetylene for welding and cutting grew very rapidly. Today the manufacture and distribution of carbide is a great industry, and it can be obtained in almost any city or distributing center in the United States or Canada.

How Carbide Is Made

Calcium is a metal obtained from limestone. Carbon is the principal element found in coal. Calcium carbide is a chemical combination of approximately sixty-two and one-half per cent of calcium and thirty-seven and one-half per cent of carbon by weight. The raw materials are crushed, thoroughly mixed, and melted in an electric furnace. After the molten carbide has solidified, it is crushed and screened to convenient sizes and packed in air tight drums.

The sizes, more often used, are known to the trade as "14 ND," "Rice," "Quarter" and "Nut." The first two sizes are fine. The "Quarter" size is called one-quarter by one-twelfth and indicates carbide which will pass through a one-quarter inch screen, but which will not pass through a one-twelfth inch screen. The "Nut" size will pass through a one and one-quarter inch screen, but will not pass through a three-eighths inch screen. These sizes of carbide are usually packed in one hundred pound air tight metal drums. Most of these drums are supplied with a screw cover and a cardboard gasket so that a part of the contents of the drum may be removed, the cover replaced, and the balance of the carbide kept away from the air. If the entire can is not placed in the generator at once, the gasket should be replaced and the cover screwed tight. Otherwise, the carbide will air-slack and deteriorate. Carbide will not burn and cannot be exploded. It is a material resembling gray stone and a cubic foot of it crushed weighs about seventy-two pounds.

Calcium Carbide Produces Acetylene

Lumps of calcium carbide when dropped into water will disintegrate and produce a gas which is known as acetylene. This gas bubbles up to the surface of the water and leaves a residue in the water which consists principally of slaked lime. One pound of carbide will yield from four and one-half to five cubic feet of acetylene. The production of acetylene from carbide requires a machine called an acetylene generator. Generators are used extensively all over the country for producing acetylene for welding and cutting. In fact the subject is so important that an entire lesson will be devoted to it to enable the student to learn how they are constructed, how operated and how the acetylene is distributed through pipe lines from them to the welding and cutting stations where the torches are connected.

Acetylene Has Characteristics Peculiar to Itself

Acetylene is not an ordinary gas. As was stated in Lesson No. 1, it contains approximately ninety-three per cent of carbon and about seven per cent of hydrogen. It is what is known as an endothermic compound. Gases generally are divided into two classes. Those which generate heat during the chemical reaction of their formation are called exothermic and those which absorb heat during their formation are called endothermic. Acetylene is one of the few endothermic gases. Carbide absorbs a large quantity of heat during its formation, a part of which heat, about 227 British thermal units* per cubic foot of gas, is passed on to acetylene when generated. If it were not for this endothermic property, the temperature of the luminous cone of flame would probably be in the neighborhood of 4,000 degrees instead of 6,300 degrees. This can be considered the chief asset of acetylene and has made it the most efficient of all gases for welding purposes.

Acetylene has another property which contributes to its usefulness. It not only develops a large amount of heat, approximately 1,650 British thermal units, but it releases the heat units so rapidly that the highest temperature of the flame is produced almost instantly. There is another peculiar characteristic which acetylene possesses also due to its chemical construction which makes it unsafe to compress acetylene into an empty tank to a pressure greater than fifteen pounds per square inch. If undissolved acetylene is compressed to a pressure higher than fifteen pounds, it becomes unstable and as the pressure increases it may split up or dissociate. Carbide when produced absorbs and holds in latent form a tremendous amount of heat. When pressure causes the gas to split up or decompose, this disturbance of the molecules releases this heat and it will extend from one molecule to the next until finally an explosion of the gas is produced. This characteristic is peculiar to acetylene and is not found in such gases as hydrogen, city gas, etc.

One cubic foot of acetylene, at sixty-eight degrees Fahrenheit and at atmospheric pressure, or 14.7 pounds per square inch at sea level weighs .0687 pounds. At the same temperature and pressure there are 14.55 cubic feet to a pound.

Acetylene Cylinders

The present acetylene cylinder is the result of much experimental work carried on during the early days of the industry. It was found that acetylene would not dissociate when compressed into cylinders containing a porous filler saturated with acetone and that under these conditions acetylene compressed to pressures as high as 250 pounds was entirely safe. All acetylene cylinders are now constructed in accordance with the specifications of the Interstate Commerce Commission. There are several makes of acetylene cylinders upon the market, all of which comply with these specifications. They are, however, made in quite a different manner, but all are constructed upon the same broad principles. An illustration of one of these is shown in Fig. 8 and this type of cylinder will be described. It consists of a seamless, drawn steel bottle, manufactured according to the same general methods used in making an oxygen cylinder.

The thickness of the walls, of course, is not as

*****A British thermal unit is the quantity of heat required to raise the temperature of one pound of pure water one degree Fahrenheit.*

great and the diameter of the cylinder is larger and the height is less. An acetylene cylinder of the 250 cubic foot size, which is ordinarily used for welding, is twelve inches in diameter, forty-four and one-half inches overall in height, weighs, when full, 215 pounds and contains approximately 250 cubic feet of acetylene when charged to a pressure of 250 pounds per square inch. The neck of this cylinder, of course, is small, only large enough for the valve to screw into it and through this small opening the filler must be forced.

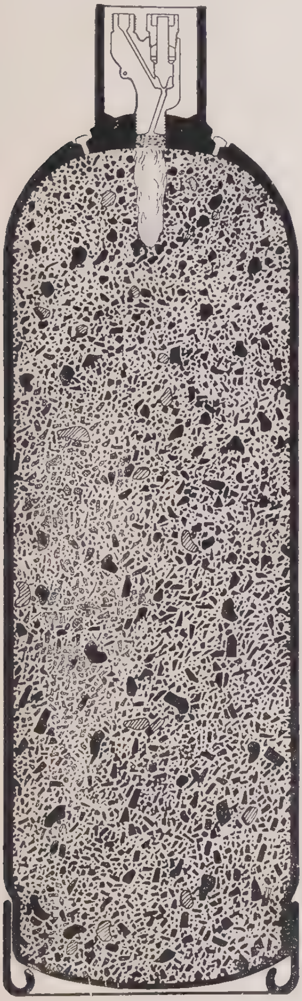


Figure 8—Sectional View of an Acetylene Cylinder. Directly Under the Cylinder Valve a Hole Has Been Drilled in the Porous Filler and Subsequently Filled with Asbestos. This is to Facilitate the Discharge of the Acetylene from the Porous Filler to the Valve. This is a Typical Seamless, Drawn Cylinder of What is Known as the Monolithic Type.

The cylinder is filled with a porous mass consisting of charcoal, infusorial earth, finely shredded asbestos and Portland cement. Due to the small opening in the neck these ingredients must be well mixed with the right amount of water and fed into the cylinder in the form of a thick paste. As the cylinder is filled it is jolted on a jolting platform operated by an eccentric shaft. After the cylinder has been completely filled with the above ingredients, it is baked in an oven for a considerable period of time until thoroughly dried out. The porosity of the filler should not exceed eighty per cent of the volume of the cylinder. The interior of the cylinder is thus divided into minute cells. The solvent ordinarily used in this country is acetone, which is a colorless, mobile liquid produced in the dry distillation of wood. It is a member of the alcohol family and possesses the property of absorbing or dissolving a large amount of acetylene. The figure usually given is twenty-five times its own volume for each fifteen pounds of pressure applied. The amount of acetone normally placed in a cylinder should not exceed forty per cent of the volume of the cylinder.

The volume of acetylene in an acetylene cylinder is determined by its weight and not by pressure gauge readings, as is the case with oxygen. It will be readily appreciated that because of the expansion of the acetylene, as well as the acetone, gauge pressure readings cannot be readily or accurately converted into cubic feet. For this reason the tare weight, as it is called, of an acetylene cylinder is established and stamped upon the name plate of the cylinder. This tare weight is the combined weight of the cylinder, the porous filling, the valve and the necessary amount of acetone, but exclusive of the cylinder cap.

When the cylinder has been fully charged up to its maximum pressure of 250 pounds, it is weighed and the tare weight, as shown upon the name plate, is deducted from the weight when full of acetylene. The difference in weight represents the weight of acetylene in the cylinder. It is usually reduced to cubic feet by multiplying this figure by fourteen and one-half cubic feet per pound. This is a commercial figure which is ordinarily used as it is convenient for calculating purposes.

When cylinders are received at a recharging plant, they are always checked to determine if they have their normal capacity of acetone. This is done by placing the cylinder on an accurate scale after all of the acetylene has been discharged into a gasometer and the gauge pressure is zero. If the weight shown is below the tare weight marked on the name-plate, acetone is added to the cylinder until these weights agree. This is necessary because when large torches are in use a certain amount of the acetone content of the cylinder sometimes passes out with the gas. Acetone is expensive and its effect upon the weld is not good and for this reason care should be taken to avoid as far as possible any withdrawal of acetone.

This can be accomplished in most instances by taking pains to see that the cylinder is upright when in use. Some welders are in the habit, particularly in outdoor work, of using the cylinder when it is lying flat upon the ground. Such practice should always be avoided. There is a generally accepted rule that acetylene should not be withdrawn from a cylinder at a rate exceeding one-fifth of its capacity per hour. If, for instance, a 250 cubic foot cylinder were in use, not more than 50 cubic feet per hour should be withdrawn for any great length of time. When the cylinder is full this rate can be exceeded, but as the pressure in the cylinder decreases acetone is likely to pass over with the gas.

Fusible Plugs

All acetylene cylinders are equipped with one or more fusible plugs. These are steel plugs, through which a hole has been drilled, the hole being filled with a fusible metal which will melt at approximately 240 degrees Fahrenheit. These plugs are screwed into the cylinder so that in case of a fire the fusible metal will melt and release the gas before the pressure within the cylinder becomes abnormally high. It is, therefore, essential that acetylene cylinders be kept away from hot radiators, furnaces, or rooms where the temperature is so high that the fusible metal might become softened. Leaks in acetylene cylinders should always be carefully guarded against and sparks and fire kept away from the cylinders.

Acetylene Cylinder Valves

Acetylene cylinder valves differ considerably in detail from oxygen valves. A hand wheel is not used, but the valve stem terminates in either a square or other shaped stem upon which a wrench must be used. This wrench should always be kept in position on the valve stem ready for any emergency while the cylinder is in operation. It is a practice of some welders to remove the valve wrench after turning on the cylinder and throw it in a tool box or put it in one of their pockets. This practice is not good, because if it became necessary to shut the cylinder off quickly it might not be possible to locate the wrench and it is difficult to shut the cylinder off without it.

There are several types of acetylene cylinder valves in use, all having outlet valve nipples which are threaded to fit a one-half inch straight pipe thread, the diameter of which is .830 inches and the threading fourteen threads to the inch, right hand. These valves have male nipples. There is another type of valve in general use for acetylene cylinders which has a female, left hand thread, the diameter of which is seven-eighths inches and the threading fourteen threads to the inch. Cylinders upon which this type of valve is used have a concave end, so that the valve is protected by the sides of the cylinder and a cap is not necessary. When regulators of the type described in this lesson are to be attached to such cylinders, an adapter is necessary.

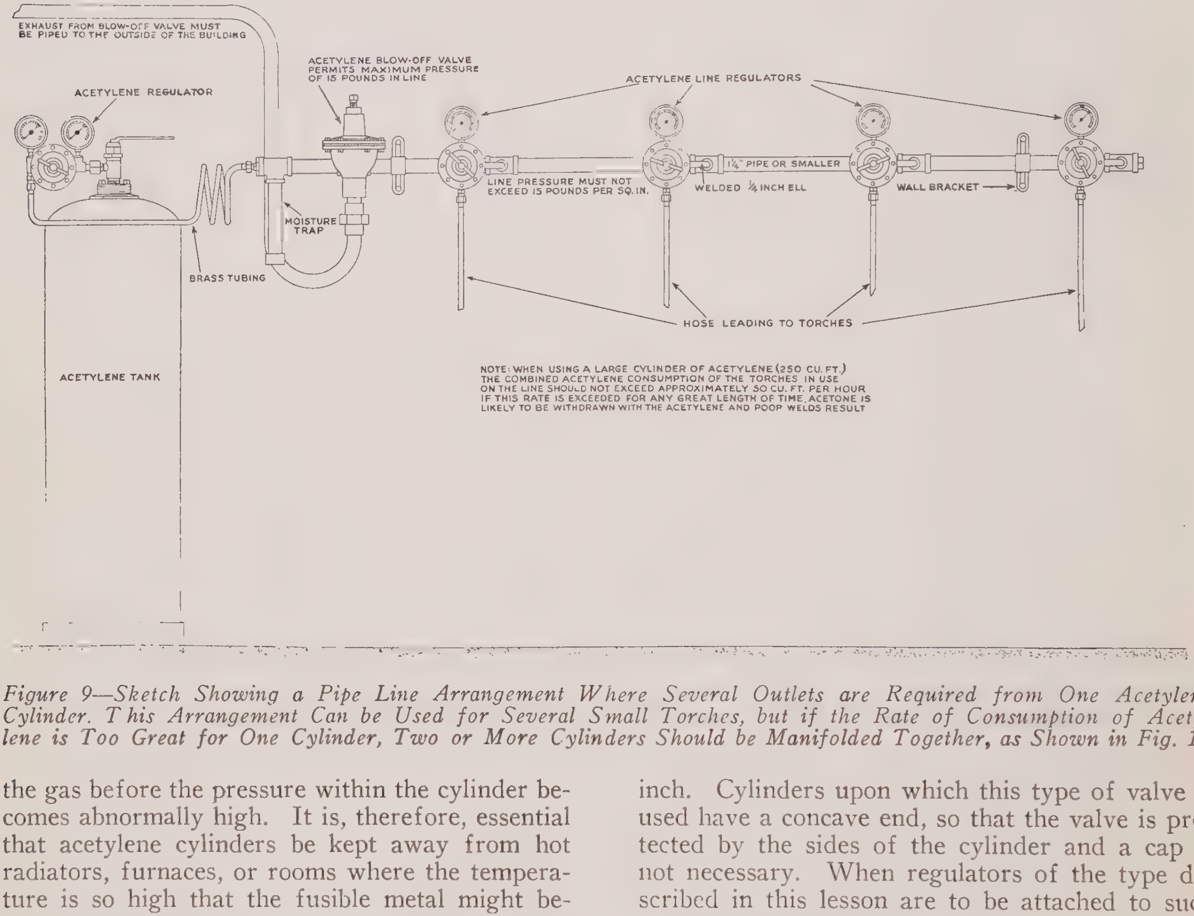

EXHAUST FROM BLOW-OFF VALVE MUST BE PIPED TO THE OUTSIDE OF THE BUILDING
ACETYLENE BLOW-OFF VALVE PERMITS MAXIMUM PRESSURE OF 15 POUNDS IN LINE
ACETYLENE REGULATOR
ACETYLENE LINE REGULATORS
1¼" PIPE OR SMALLER
LINE PRESSURE MUST NOT EXCEED 15 POUNDS PER SQ. IN.
WELDED ¼ INCH ELL
WALL BRACKET
MOISTURE TRAP
BRASS TUBING
HOSE LEADING TO TORCHES
ACETYLENE TANK
NOTE: WHEN USING A LARGE CYLINDER OF ACETYLENE (250 CU. FT.) THE COMBINED ACETYLENE CONSUMPTION OF THE TORCHES IN USE ON THE LINE SHOULD NOT EXCEED APPROXIMATELY 50 CU. FT. PER HOUR IF THIS RATE IS EXCEEDED FOR ANY GREAT LENGTH OF TIME, ACETONE IS LIKELY TO BE WITHDRAWN WITH THE ACETYLENE AND POOR WELDS RESULT

Figure 9—Sketch Showing a Pipe Line Arrangement Where Several Outlets are Required from One Acetylene Cylinder. This Arrangement Can be Used for Several Small Torches, but if the Rate of Consumption of Acetylene is Too Great for One Cylinder, Two or More Cylinders Should be Manifolded Together, as Shown in Fig. 10.

Valves on Empty Cylinders Should Be Closed

It is particularly important that an empty acetylene cylinder should have its valve closed when the regulator is removed from it. This is due to the fact that when a cylinder is cool, the gas may seem to be entirely exhausted, however if the temperature of the room and cylinder is raised, the small amount of acetylene which is still held by the acetone may be freed and it will then pass through the open valve into the room. Acetylene is inflammable and only about three and one-half per cent of it in a room is necessary to cause an explosive mixture. Empty acetylene cylinders with the valves open shipped in a box car have discharged enough acetylene to cause an explosion, solely because of an increase in temperature.

Acetylene Pipe Line from Cylinder

As has been stated before, it is unsafe to deliver acetylene into a pipe line at a pressure in excess of fifteen pounds per square inch. It is, therefore, never safe to connect the acetylene cylinder direct to a pipe line and permit the full cylinder pressure of 250 pounds per square inch to enter the line, except under circumstances where a specially constructed manifold is used. For this reason the arrangement of piping, and the cylinder utilizing a regulator, shown in Fig. 9, should be used. The acetylene cylinder, to which is attached an acetylene regulator, is shown to the left of the figure. The pressure within the cylinder, 250 pounds when full, is reduced by the regulator to a pressure of twelve pounds. Acetylene under twelve pounds pressure is, therefore, delivered to the pipe line and leaves the line through each station regulator, called line regulators. These regulators reduce the pressure from twelve pounds to a suitable working pressure for the torch, depending upon the tip in use. This arrangement is particularly valuable where a number of small torches are to be used simultaneously, and it is necessary to have very accurate regulation of the pressure of the acetylene. A blow off valve is provided in the line which is set to blow at a pressure of fifteen pounds per square inch. The outlet of the blow off is piped to the outside of the building. There is a flexible brass pipe coil used between the outlet of the regulator and the inlet of the pipe.

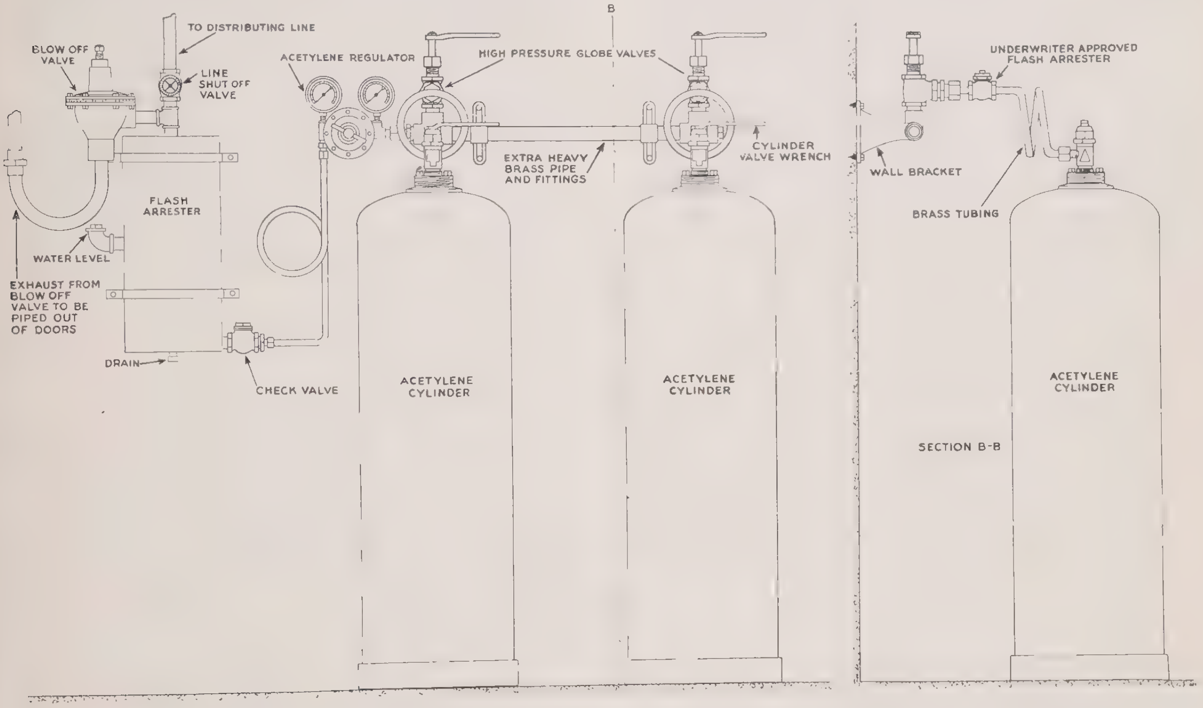

TO DISTRIBUTING LINE
BLOW OFF VALVE
LINE SHUT OFF VALVE
ACETYLENE REGULATOR
HIGH PRESSURE GLOBE VALVES
B
UNDERWRITER APPROVED FLASH ARRESTER
FLASH ARRESTER
EXTRA HEAVY BRASS PIPE AND FITTINGS
CYLINDER VALVE WRENCH
WALL BRACKET
BRASS TUBING
WATER LEVEL
EXHAUST FROM BLOW OFF VALVE TO BE PIPED OUT OF DOORS
DRAIN
CHECK VALVE
ACETYLENE CYLINDER
ACETYLENE CYLINDER
ACETYLENE CYLINDER
SECTION B-B

Figure 10—A Sketch Showing an Acetylene Cylinder Manifold. Cylinder Manifolds are not Made of Ordinary Pipe, but are Constructed of Extra Heavy Pipe and Fittings, to Conform to the Rules and Regulations of the National Board of Fire Underwriters.

Acetylene Manifolds

When a consumption of acetylene greater than should be normally removed from one cylinder is required, it may become necessary to use two cylinders connected together with an acetylene manifold. Acetylene manifolds are especially constructed for the purpose in accordance with the rules and requirements of the National Board of Fire Underwriters. They are made of extra strong brass pipe to which high pressure fittings and high pressure globe valves are attached. Flexible brass tubes extend from each globe valve to the acetylene cylinders with an Underwriters' approved flash arrestor inserted in each tube. Copper tubing must not be used for acetylene.

At the end of the manifold an acetylene regulator is attached, connected by a flexible brass tube to the inlet of a water seal flash arrestor, similar to those used upon acetylene generators. This flash arrestor has a blow off valve, which is set for a maximum pressure of fifteen pounds per square inch, attached to its outlet piping. The outlet of the blow off is connected to the outside air. The pipe line from the flash arrestor leads to as many outlet line regulators as are required, similar to those shown in Fig. 9.

The water seal flash arrestor shown to the extreme left of Fig. 10, consists of a small tank filled with water to the level of the overflow and filling plug, and a check valve below the water line. The acetylene passes downward from the regulator through the flexible coil and through the check valve bubbling up through the water and passing into the line through the outlet of the flash arrestor at the top. In case of a backward flow of oxygen, caused by stoppage of the torch or of a flash back into the line, the check valve would close, not permitting the water to be forced backward to the regulator and cylinders. The backward pressure would therefore stop at the flash arrestor and the pressure would be relieved through the blow off valve to the outside air.

Honesty

One of the most important characteristics of a welder is honesty. It is very easy with a torch to gloss over a defect, to include particles of slag in the weld, or to weld over the surface and not penetrate to the full depth of the metal. Such practice means but one thing, a weak, poor weld which will probably break in service, and which may cause accidents or even deaths. Any weld can be made stronger than the metal itself by building up the weld thicker than the plates and by careful and skillful handling of the torch and the welding rod. Penetration clear through the metal is essential in making a strong weld. A man who is content to gloss over the surface and who will not take the time or the trouble to use the best skill he can attain to make a sound, honest weld might better stop right in the beginning and take up some other trade, rather than continue with a process which requires fundamental honesty and conscientious workmanship.

It is, therefore, doubly important that a man who is about to follow this trade be certain that he is willing to make the effort to develop the skill which will make him an efficient welder and to practice his trade honestly and conscientiously. These remarks, however, should not be taken to indicate that welding on a large scale cannot be carried out with every assurance that the result when completed will meet all engineering requirements.

Photographs of Welded Steel Plates

While this lesson refers particularly to the welding of one eighth inch steel, and the practice work which a student must do to become proficient in welding a bead upon steel of this thickness, he should as quickly as possible become familiar with the appearance of welds made in heavier steel plates and the manner in which the edges of these pieces of steel are bevelled. For this reason six photographs of typical welds made in various thicknesses of steel plates are illustrated. These are actual welds made by a welder of fair experience and they are all sound welds penetrating clear through to the bottom of the plate. By studying these photographs the student will become accustomed to the appearance of welds made in heavier plate and will be ready for this work when it appears in a future lesson.

Chart No. 4, page 15, Lesson No. 2, illustrates the bevelling of steel plate three-sixteenths inches and over in thickness. This bevel is not made clear through the plate to its other edge, but an edge one-sixteenth of an inch in thickness is left in order that the flame may not melt through the steel too quickly and form beads of metal extending below the plate. In the case of the double vee weld, the welding is accomplished from both sides and a stronger weld is the result.

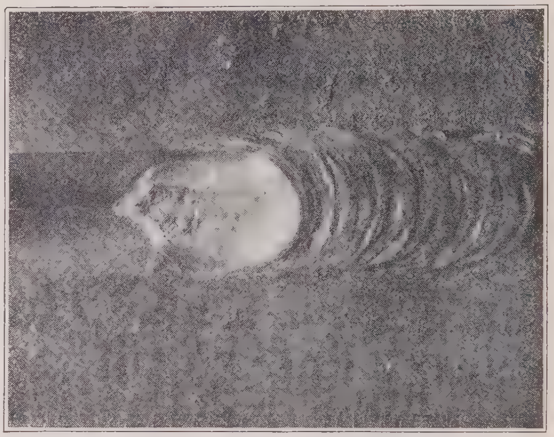


Figure 11—Photograph Showing a Weld Made Between Two Pieces of One-Half inch Steel Plate. This Weld is Just as it was Left by the Torch Without any Cleaning Up of Any Kind. The Edges were Bevelled at 45 Degrees with the Top Surface of the Plate and the Distance Between the Top Edges of the Bevel is Seven-eighths Inch. The Width of the Puddle and, therefore, the Finished Weld is One Inch.

For very heavy castings, the circular vee is more economical and equally as efficient as the straight bevel. The width A, Chart No. 4, is then large enough to admit the tip so that the

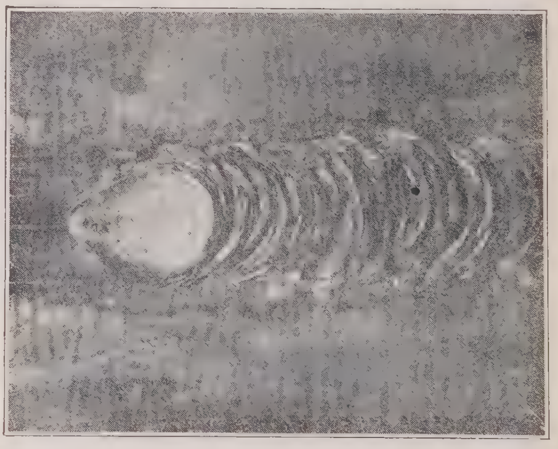


Figure 12—This Photograph is of a Weld Made Between Two Pieces of One-Half Inch Steel Plate but the Weld has been Cleaned Up with a Wire Brush to Remove Scale and Oxide. The Bead has not been Built Quite as High as in Figure 11, but it is a Thoroughly Sound, Strong Weld.

weld can be made clear to the bottom of the casting. In the following photographs, both the single vee and the double vee welds are illustrated, but not the circular vee, which is shown only in a sketch in Chart No. 4. The reason for bevelling the plates must now be evident to the student. If the steel is one-eighth inch in thickness, the flame will readily melt clear through the plate and fuse it to the bottom edge. If, however, the metal is thicker in section and the edges are not bevelled but are straight and butted together adjacent to each other, it is impossible to fuse the metal clear through to the bottom of the sheet without having the molten upper surfaces flow together. In this instance the weld would look all right on the top and the bead might have the appearance of an excellent weld, but if the plates were turned over and the other side examined, it would be found that the fused metal extended only about half way through.

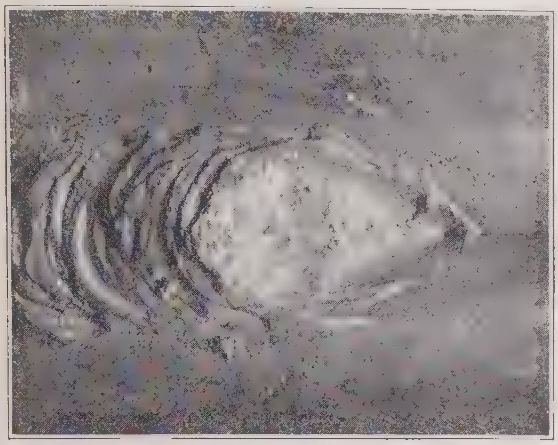


Figure 13—This Photograph Shows a Weld between Two Pieces of Three-Quarter Inch Steel Plate.

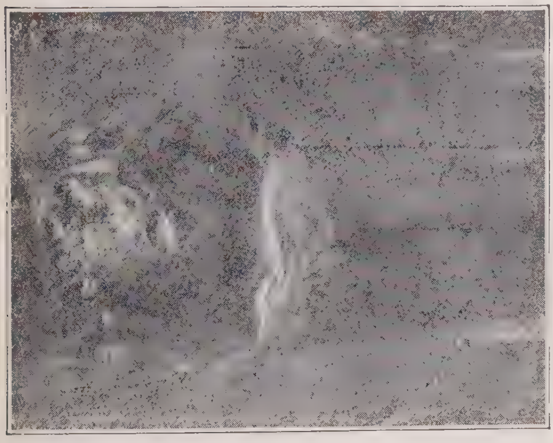


Figure 14—This is a Weld Made Between Two Pieces of Three-Quarter Inch Steel Plate, But it was Made by a Different Welder and in a Somewhat Different Manner. It will be Noted that the Puddle is Almost Two Inches in Width. The End of the Weld is Steeper in Inclination Than That Shown in Figure 13, but the Weld is Thoroughly Sound and Penetrates Clear Through the Plates.

For this reason the heavier sections are almost always bevelled to an angle of 45 degrees with the surface of the plate. This gives a sufficiently wide bevel to enable the welder to fuse the steel clear to the lower surface and then build up the weld gradually until the full section has been completed. The photographs illustrate welds which were made in accordance with the recommended practices in these lessons and which appear just as they were finished by the torch. There is still a slight layer of scale over them and with one exception, Fig. 12, they have not been cleaned at all. Fig. 12 was brushed up somewhat with a wire brush to remove the scale and oxide on the surface and consequently looks a little brighter than the others

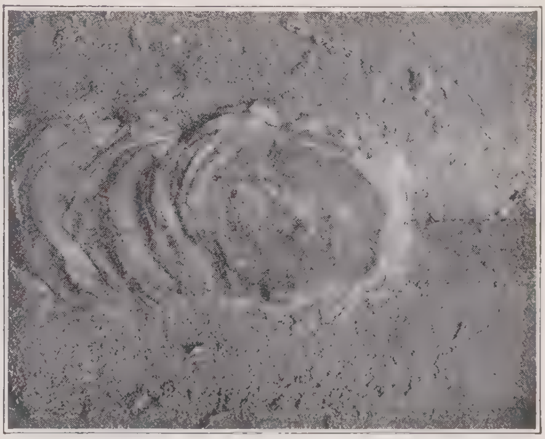


Figure 15—This is a Weld Called a Double Vee Weld, Because the Bevels are Made from Each Side of the Plate and the Welding was Also Done from Each Side of the Plate. The Thickness of the Steel in This Instance is One Inch. A Double Vee Weld Made in This Manner is a Stronger Weld as a Rule Than the Single Vee Type. It Also Involves Less Filling Rod as the Total Area of Both Veed Sections is One-Half of the Area of the Section if the Single Vee is Used. This Type of Weld, Therefore, Requires Less Adding Material Than the Single Vee Type.

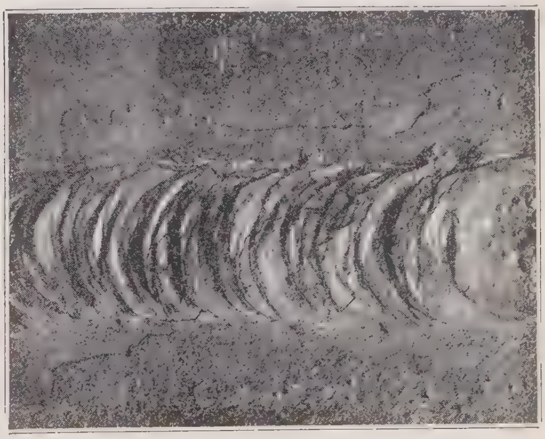


Figure 16—This Photograph Shows a Completed Weld of the Double Vee Type. It is an Excellent Example of a Weld in Heavy Steel Plate and Has a Strength Without Question Exceeding the Strength of the Plate Itself.

Rules for Safe Handling of Cylinders

OXYGEN

1. **Don't use oil—you may get hurt. Compressed oxygen plus oil is explosive.** Allow no oil or grease of any kind to come in contact with valve, regulator or any other portion of the cylinder or apparatus.
2. When returning empty oxygen cylinders to manufacturer, lower portion of green tag attached to cylinders should be removed at the perforated line. Any green sticker label found pasted to the cylinder should be removed. Bill of lading should specify that the cylinders are empty and serial numbers of the cylinders should be noted thereon.
3. Cylinders of oxygen, except those in actual use and in excess of approximately one day's supply required in any one department or point about the shop, should be stored in a place where they will not be tampered with by unauthorized persons.
4. Oxygen cylinders should be stored in a safe, dry place, where they will not be exposed to heat of stoves, radiators, furnaces, or in the direct rays of the sun. Heat will increase the pressure and it may cause the safety plug or disk to melt or blow, thus allowing oxygen to escape, resulting in waste. If the escaping oxygen comes in contact with even the smallest flame it has such a tremendous influence upon combustion that a quick raging fire is liable to result.
5. Cylinders of oxygen are never to be stored in the same room used for the storage of calcium carbide, cylinders of dissolved acetylene or other fuel gases, or with acetylene generators.
6. Open flames of any description shall not be employed in any building used for the storage of oxygen cylinders.
7. If cylinders are stored on the ground or open platforms, such locations should not be adjacent to points where there is a large amount of combustible material.

   Note: While oxygen itself will not burn, its effect in aiding combustion, once a blaze is started, makes it important that rules 4 to 7 inclusive be carefully observed.

ACETYLENE, HYDROGEN, ETC.

8. Cylinders should be stored in a safe, dry, well-ventilated place where they will not be unduly exposed to the heat of stoves, radiators, furnaces, or the direct rays of the sun. Heat will increase the pressure, or it may melt the fusible safety plug with which most cylinders are provided and which melts at a temperature of approximately 212 degrees to 220 degrees F.
9. No open flame, grinding tools, or spark-emitting devices shall ever be used within the storage building or compartment, and all artificial lights shall be incandescent electric and shall be installed in accordance with the "National Electrical Code for Rooms in which Inflammable Vapors May Exist." Electric light switches, telephone and all other apparatus which may cause a spark must be located on the outside of building. All lamps shall be enclosed in vapor-proof globes of the marine type.
10. Cylinders of dissolved acetylene shall always be stored standing upright with valve end up.
11. When shipping empty dissolved acetylene cylinders and other fuel gas cylinders to manufacturer, lower portion of red shipping tag attached to cylinders should be removed at the perforated line. Any red sticker label found pasted to cylinder wall should also be removed. Bill of lading should specify that the cylinders are empty enumerating the type and individual numbers of such cylinders.
12. Under no circumstances attempt to transfer acetylene from one cylinder to another and never under any conditions attempt to compress acetylene into a cylinder. This work should only be performed by acetylene charging plants, and under conditions which comply with Interstate Commerce Commission Regulations.

GENERAL RULES

13. When cylinders of dissolved acetylene, hydrogen, liquid fuel gases or vapors are not in use, outlet valves must be kept tightly closed, even though cylinders may be considered empty, and valve caps replaced.
14. Oxygen cylinders and acetylene, hydrogen or other fuel gas cylinders shall not be transported or lifted by crane or derrick except when they are in a cradle or substantial stand, and cylinders shall never be handled with electro-magnets or with rope or chain slings.
15. Cylinders should be handled carefully, should never be dropped, and should be placed so they will not fall nor be struck by other objects. Knocks, falls or rough handling are liable to damage the cylinder, valve or fuse plugs, and cause leakage, and may even result in an explosion.
16. When **exhausted, cylinders should be returned as rapidly as practicable** to the storage building or place, and from there **to the manufacturer.** Empty cylinders should be marked "EMPTY" and stored apart from full cylinders to prevent confusion. **Valve protection caps should be replaced.**

Job Sheet No. 3

Welding One-Eighth Inch Steel With Adding Material

1. The equipment required is the same as used in Lessons Nos. 1 and 2 with the exception that a slightly larger tip is needed. A tip assembly corresponding to a No. 2 is of the right size. A good supply of sheet steel one-eighth inch thick should be available as well as some welding rod three thirty-seconds of an inch in diameter.
2. Place a piece of sheet steel across two fire bricks as shown in Fig. No. 1.
3. Open the cylinders, adjust the regulators and light the torch as previously described.
4. Hold the torch in the right hand in such a position that the tip is in line with the weld horizontally and at an angle of about 45 degrees to it vertically. If the tip of the torch is bent to an angle of forty-five degrees, similar to the ones illustrated, then a very simple and convenient way of holding the torch is shown in Figures 1, 2 and 3. The welding rod should be held in the left hand and about six or eight inches of it bent to a right angle, as shown in the sketches, by holding the rod in the flame until it has been heated to a dull red and then pressing the end against the bricks until the proper angle is reached.

   The rod is bent to this angle so that the student may hold it in a natural and restful way while working.

   The angle between the rod and the flame should be approximately ninety degrees.
5. Pass the flame over the sheet metal several times in order to heat the metal slightly, then direct the flame steadily upon one spot at the right hand end of the piece, keeping the end of the luminous cone about one-sixteenth inch away from the metal. Just before the metal begins to melt, bring the end of the welding rod under the flame. If this action is timed correctly, both the rod and the sheet will melt at the same time and form a puddle of molten metal on the plate. As soon as the puddle is formed, the semi-circular motion of the torch and the alternating cross motion of the rod should be started. Care should be taken to keep the rod within the puddle as the rod will stick to the plate if it touches the cooler edges. This will interrupt progress and spoil the appearance of the weld or bead as it is generally known. On one-eighth inch metal this bead should be approximately three-eighths inch wide. As the welding rod melts and fills up the puddle, the torch and rod should be moved slowly to the left. Before moving forward, be sure that the added material is actually fused to the sheet or base metal and not merely laid on it in drops. If the weld is carried forward too rapidly the metal will not fuse, while if the progression is too slow the metal is very likely to be burned. Carry this bead to the end of the piece of steel.
6. Shut off the torch and practice the motions of the torch and rod until the muscles of the arms become thoroughly accustomed to them. These motions are very important. When the flame is in the positions shown in Figures 1 and 3, it is heating the metal ahead of the puddle, thus making sure that the puddle is moved forward, the weld will penetrate clear through the section. The first thing the student should acquire is the ability to perform these motions with regularity. It is not necessary to move the rod and torch at a high rate of speed, in fact, a slower motion is desirable, as a slower movement promotes better fusion.
7. Light the torch again and adjust the valves until a neutral flame is obtained.
8. Recalling the movements just practiced, make a second bead across the plate from right to left.
9. Repeat the exercise until it is possible to make a smooth, even bead that is well fused to the sheet metal. A photograph of such a weld is shown in Fig. 4. This is one of the most important lessons in the course, as it trains the welder to co-ordinate the movement of his two hands and teaches him the meaning of a well fused weld.
10. After becoming proficient at making a bead on the surface of a piece of steel, select two more pieces of steel and lay them across the fire bricks so that their edges are about one-thirty-second of an inch apart. Tack neatly at each end and proceed to weld the two pieces together by making a bead directly over the space between the plates. Be sure that the weld has penetrated to the bottom of the crack. Repeat this exercise again and again until there is no doubt left as to the penetration of the weld, appearance of the bead, and the fusion of the metal.

Questions

1. Describe the semi-circular method of welding.
2. What are the purposes of the different movements?
3. What is a bead?
4. Where should the acetylene valve wrench be kept while the cylinder is in use?
5. What is the composition of air?
6. What are the principal methods used for producing oxygen?
7. Give a brief description of the one most used.
8. What is the water capacity of the usual size oxygen cylinder?

9. How many cubic feet of oxygen does the cylinder normally contain?
10. A welder is working out of doors where the temperature is 20 degrees above zero. The gauge on his oxygen regulator indicates that his tank contains 700 pounds pressure. How many cubic feet of oxygen remain in the cylinder?
11. What is an oxygen manifold?
12. What is it made of?
13. What is its purpose?
14. What is calcium carbide?
15. Will it explode?
16. How is acetylene made?
17. What is acetylene?
18. How much does it weigh?
19. How much acetylene is produced by one pound of calcium carbide?
20. Under what conditions may acetylene be safely compressed?
21. How much acetylene under fifteen pounds pressure will one volume of acetone absorb?
22. Describe the construction of a monolithic acetylene cylinder?
23. What is a "fusible plug"?
24. What is its purpose?
25. Should acetylene cylinders be used while lying on their sides? Why?
26. Why does acetylene produce such an intense heat when burned with oxygen?
27. Why is it important to keep the valves on empty cylinders closed?
28. Should surplus oxygen and acetylene cylinders be stored in one room?
29. Should oxygen and acetylene cylinders be protected from heat? Why?
30. What is the difference in construction between an oxygen cylinder manifold and an acetylene cylinder manifold?

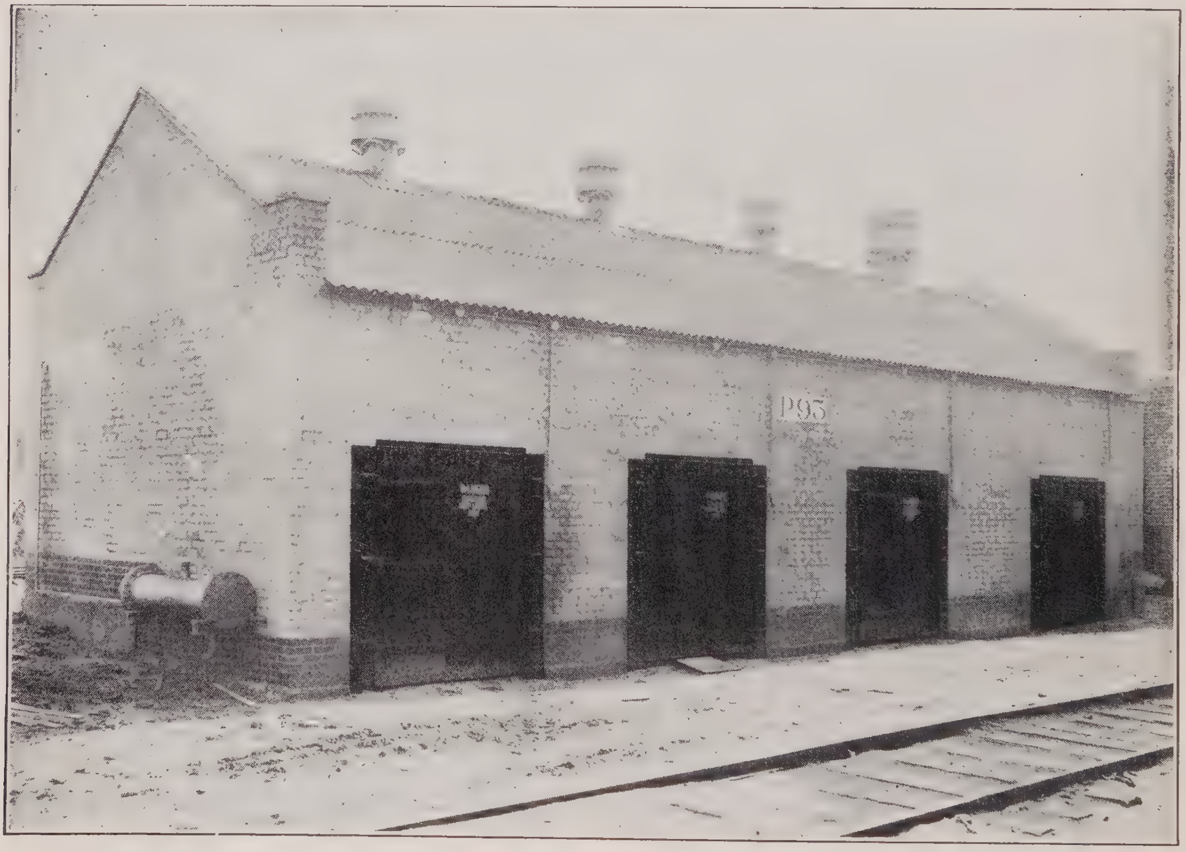


Figure 17—Photograph Showing a Typical Gas House for an Industrial Plant. The Door at the Extreme Right of the Photograph Is the Oxygen Manifold Room, an Interior View of Which Is Shown on Page 88. The Next Door to the Left Is the Carbide Storage Room and the Third Door from the Right the Acetylene Generator Room, an Interior View of Which Is Shown Upon Page 58. The Door to the Extreme Left Enters a Room Used for Other Purposes and Having No Connection with the Generation of Acetylene or the Distribution of Oxygen. Installations Like This One Are Quite Common in Large Industrial Plants.

Lesson No. 4

Vertical Welding of Sheet Metal

Cutting, Acetylene Generators and Shop Pipe Lines

WELDING is not always done on a welding table at an operator's convenience, although it is best wherever possible to make a weld in a horizontal position and in such manner that the welder is comfortable. There are many cases, however, where vertical welding or overhead welding is necessary. For instance, where two pieces of pipe are to be joined together, both of which are in a fixed position. In such a case the weld must be made completely around the circumference of the pipe and welding, therefore, must be accomplished in vertical, horizontal and overhead positions. Sometimes the assembly of a tank or a weld on a firebox necessitates vertical welding. There are, of course, many other instances where vertical welding is required.

For this reason it is necessary that the student learn to weld vertically as well as horizontally. To be a good all around welder he must, in fact, be able to weld in any position. In this lesson the student is taught to make a bead and a weld vertically by the semicircular movement method. The movement of torch and rod is similar to that of the horizontal weld fully described in Lesson No. 3. The position of the torch and the welding rod, as well as the operator, however, differs somewhat if the work is at a level with his head. The position illustrated in Fig. 1 is about the same and shows the work set upright on a welding table.

The practice work of this lesson consists in making beads upon pieces of steel one-eighth inch in thickness set on top of the welding table and if necessary leaning against a few fire bricks. These pieces should be set as nearly vertical as possible and welding begun at the bottom. The welding is carried upward using the semicircular movement of the torch and the cross movement of the welding rod in similar manner to the horizontal weld. Greater skill is required, however, to prevent the puddle from melting too quickly and running down the side of the sheet.

Vertical welding is little more difficult than horizontal welding if the welder understands the proper manipulation of the torch to maintain the sheet and the rod at just the right temperature. In this respect the student should remember the flame illustrated in Fig. 5, page No. 17, Lesson No. 2, and the fact that at the luminous cone the temperature is 6,300 degrees, while at the tip of the envelope of the flame the temperature is 2,300 degrees. By drawing the luminous cone of flame a little further away from the metal, the temperature can be controlled almost exactly. It is necessary to watch the back rim of the puddle closely to prevent the molten metal from running over the rim and dripping down the side of the sheet. The movement of the torch upward along the line of weld must be at just the right speed to

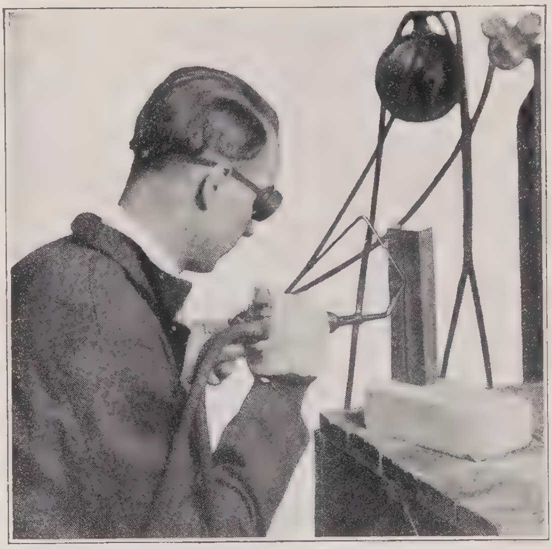


Figure 1—Vertical Welding by the Semicircular Method. Two Pieces of One-eighth Inch Angle Iron Have Been Set Upon a Brick on the Welding Table. The Operator is Seated on a Stool and is Holding the Torch and the Rod in a Generally Similar Manner to That Used in Making the Horizontal Weld. This Position May Change, However, as the Height of the Weld Increases, When it May Become Necessary for the Operator to Turn the Torch Over in a Reversed Position to That Shown in the Photograph. The Position of the Torch is Entirely Dependent Upon the Relative Position of the Operator and the Work.

allow the back rim to solidify before it becomes too hot and runs over. It will require more practice to make a good vertical weld and, therefore, the student should practice vertical beading over and over until he becomes proficient.

Cutting

Nothing has been said in these lessons as yet about the process of cutting, or the cutting torch. It will soon be necessary for the student to use the cutting torch in connection with the work which he is doing and he, therefore, should learn how to use the torch and the principles of the cutting process as early in the course of instruction as possible. Both will, therefore, be fully described in this lesson.

Oxygen has a peculiar affinity for iron and steel. When steel is cold, the oxygen in the air causes it to rust. Rust is oxide of iron and the chemical reaction which produces it is quite slow, partly because the air is diluted with four-fifths nitrogen, an inactive gas, and contains only one-fifth oxygen and partly because the steel is cold. If the steel is heated, the action is much more rapid and that is why scale or iron oxide quickly forms on top of the molten puddle when making a weld after the torch has been removed and the hot metal exposed to the air. Now if steel, heated red hot, is brought into contact with pure oxygen it will completely burn up. In other words, in the presence of oxygen, the iron in the steel burns into what is known as magnetic oxide of iron. The chemical formula for this oxide is Fe_3O_4, merely another way of stating that three parts of iron, called Fe, combine with four parts of oxygen, called O, to produce complete combustion. This can be reduced to pounds by figuring the relative weight of an atom* of iron and an atom of oxygen. The atomic or combining weight is the relative weight of an atom of each element compared with that of hydrogen.

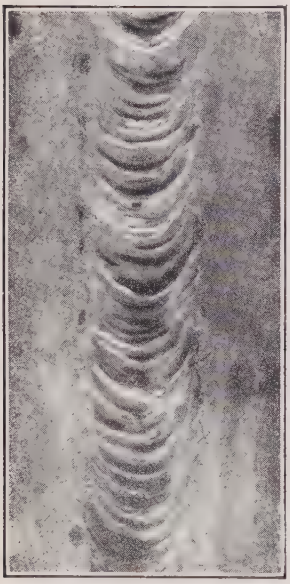


Figure 2—A Photograph of a Completed Vertical Weld. This Weld Was Made by the Semicircular Movement Method, as Indicated in Figure 1 and Was Started at the Bottom of the Seam and Continued Upward. It is a Close-up View of the Weld Shown in Figure 1.

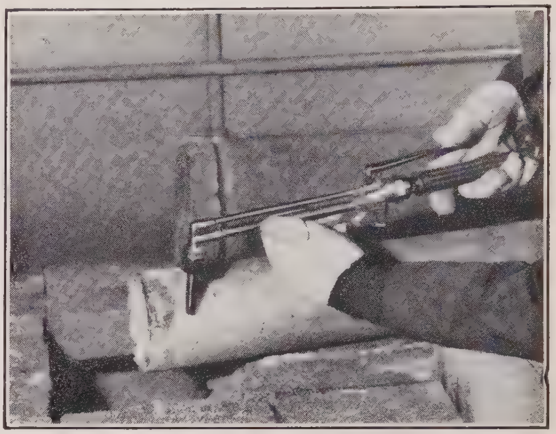


Figure 3—Cutting with the Cutting Assembly of a Combination Welding and Cutting Torch. The Operator is About to Cut a Piece of Pipe and the Position of the Torch is That Which Would Normally be Taken in Beginning a Cut in a Piece of Pipe or a Round Steel Shaft.

From these figures it is very easy to show that theoretically one pound of iron requires .382 of a pound of oxygen to produce complete combustion. This expressed in cubic inches and cubic feet with which the welder is more familiar means that one cubic inch of iron requires 1.3 cubic feet of oxygen to completely burn it up.

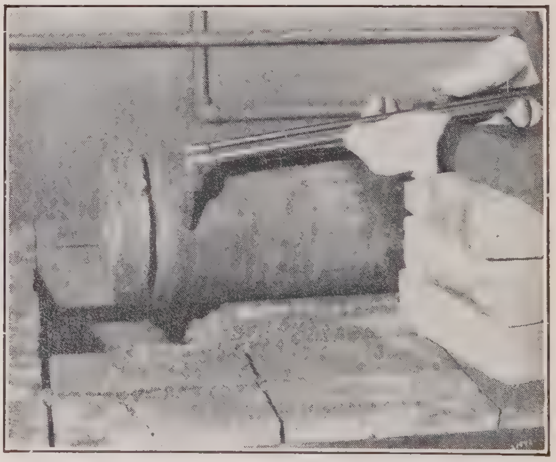


Figure 4—A Cutting Torch Held in Position to Begin a Cut on an Eight Inch Steel Shaft. The Torch Should be Held with the Preheating Flames Directed Against the Side of the Shaft for a Few Moments Until a Spot on the Shaft Becomes Heated to a Red Heat. The Torch Should Then be Turned so That the Tip is Vertical and the Button Valve of the Oxygen Cutting Jet Pressed Down, Thus Releasing Pure Oxygen Which Will Flow from the End of the Tip and Strike the Heated Metal at High Velocity. The Cut Will Almost Instantly Start and the Slag Will Run Out of the Bottom of the Cut as it Continues. The Object is to Direct the Torch Against the Shaft in Such Manner That a Pocket Will Not Form in the Metal and the Molten Oxide and Slag Fly About the Room.

An atom is the smallest particle of matter that can enter into chemical combination.

As an example, suppose a piece of steel four inches in thickness and ten feet, or 120 inches, in length was to be cut, having a kerf or slot made by the cutting torch one-quarter inch in width, the amount of iron burned up would be 4 x ¼ x 120 or 120 cubic inches. As one cubic inch requires one and three-tenths cubic feet of oxygen to completely burn it up, 120 cubic inches would, therefore, require 156 cubic feet.

These are, of course, theoretical figures based upon pure iron and pure oxygen and an entirely theoretical consumption figure, in other words, all of the conditions are perfect. There is a peculiar thing about cutting, however, and that is the fact that the practical cutting of steel instead of pure iron, with oxygen which is usually about ninety-nine and one-half per cent pure, is even more efficient than the figures developed by theory indicate. The reason for this is quite simple. In cutting with the torch the iron in the kerf or slot is not entirely consumed by the oxygen. A considerable proportion of it, stated in some instances to be as high as thirty per cent, is loosened by the oxygen and blown out at the bottom of the cut, not as iron oxide, but as unconsumed iron. It, therefore, often requires less oxygen to make an actual cut than would be shown by the theoretical figures.

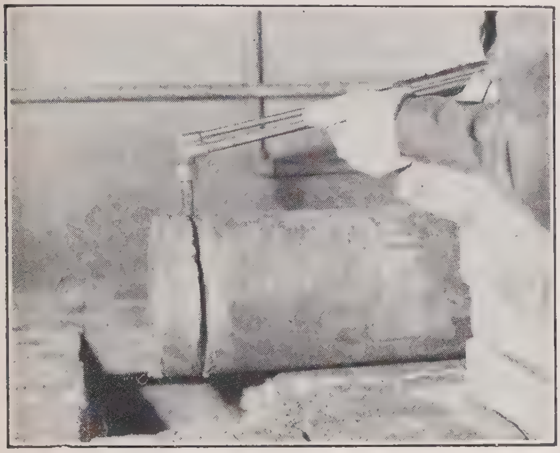


Figure 5—Shows the Position of the Torch as the Cut is Being Completed. In Making Heavy Cuts with the Torch, Arrangements Should Be Made if Possible to Rest the Left Arm Upon Fire Bricks or Some Other Convenient Support and to Protect the Hands and the Body from the Severe Heat.

The Cutting Torch

Before proceeding further the student should know what a cutting torch is and how it differs in detail from the welding torch with which he is already familiar. Instead of one large flame issuing from the tip, the cutting torch has several small flames called preheating flames surrounding a central opening through which the cutting jet of pure oxygen passes. The preheating flames are exactly like small welding flames and are intended only to heat the steel red hot immediately prior to starting the cut. They also afford sufficient auxiliary heat to maintain the cutting action, particularly when the iron or steel is coated with rust or contains sand or slag, as is often the case in the cutting of risers* from steel castings.

The question which almost always enters the mind of the man who is not familiar with cutting is how these little preheating flames supply sufficient heat to cut a heavy section of metal perhaps twelve or fifteen inches in thickness. The answer is very simple. One who is not familiar with cutting does not realize the tremendous heat which is developed by the combustion of the steel in an atmosphere of oxygen. Ordinarily in cutting a piece of six inch steel the heat developed by the combustion of the steel and the oxygen will be ten times greater than that developed by the preheating flames. Therefore, after the cut is once started, the combustion of the steel continues to heat the metal down through the cut as the cutting jet progresses forming a deep slot.

Cutting tips are constructed with four, five and six preheating flames, depending upon the manufacture of the torch. The tips are interchangeable and there are sizes ranging all the way from No. 0 up to No. 6. The diameters of the preheating and the cutting ports vary with each size of tip from the smallest, used for cutting the thinnest sections of metal, up to the largest tip, used for very heavy cutting.

The cutting torch differs considerably from the welding torch because in cutting, an additional valve, called the cutting valve, controlling the

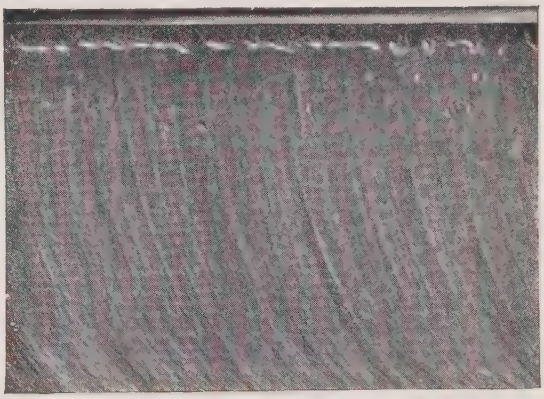


Figure 6—Photograph of a Hand Cut Made in Steel Approximately One Inch in Thickness by Guiding the Cutting Torch along a Straight Bar. The Cut Was Exceedingly Smooth and the Lines of "Lag" are Clearly Indicated. The Torch Moved Along the Cut More Rapidly than the Combustion of the Steel Clear Through the Section Could Take Place and for This Reason the Lines of the Cut Lag to the Rear Instead of Projecting Vertically Downward.

**A riser from a casting is a neck or head of excess metal placed above the heavier sections of a casting to act as a reservoir of molten metal to feed more metal to any cavities which may occur in the casting. When steel castings are removed from the sand the risers are usually cut off close to the casting with a cutting torch.*

high pressure jet of oxygen used for cutting is required. Fig. 8 shows a sectional view of a cutting torch. The acetylene valve and the oxygen preheating valve are the thumb screw valves in the lower right hand corner of the illustration. These control both oxygen and acetylene, the oxygen passing through the upper inlet nipple to the right of Fig. 8 and through a by-pass port to the oxygen valve. The oxygen gas passes through the oxygen preheating tube, which is surrounded by the acetylene tube, to the head and the tip of the torch where both oxygen and acetylene are mixed in the tip in equal volumes to produce the small preheating flames surrounding the cutting jet. In the end view of a tip, shown in Fig. 9, the relative position of the preheating ports and the central cutting jet are shown. The preheating flames are controlled and adjusted by the oxygen and acetylene valves shown at the right in Fig. 8.

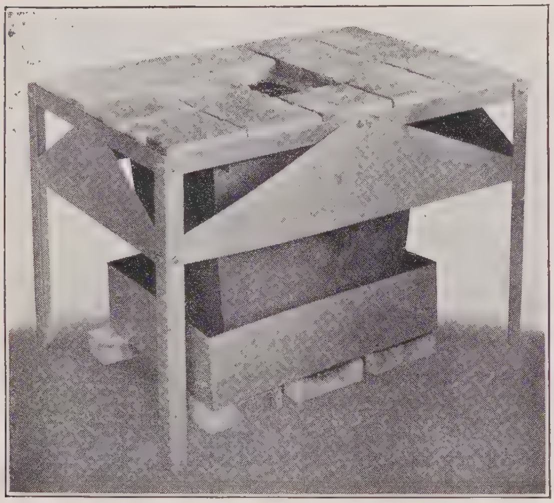


Figure 7—This is a Photograph of a Very Convenient Welding and Cutting Table for School Work. There is a Hole in the Center of the Table, so That Pieces to be Cut May Be Extended Over the Hole and the Hot Oxide and Sparks Delivered Down into the Box below the Table without Flying about the Floor. The Table is Bolted instead of being Welded that it might be Taken Apart and Shipped More Conveniently. Under Normal Conditions it could be Welded to Better Advantage. The Rectangular Apron Extending from under the Table to the Box is Held by Wires to the under part of the Table and the Box can be Slid out from Under this Apron When Necessary to Empty it of Slag and Pieces of Metal. The Box is Supported on Fire Bricks because it will Become Hot and should not Rest Upon a Wooden Floor.

The Cutting Jet

The cutting jet of oxygen is under higher pressure and may vary from five or ten pounds up to 150 pounds, depending upon the cutting to be accomplished and the wishes of the operator. The cutting jet is controlled by a lever type valve having a thumb button in the upper part of the handle of the torch and a lever and a stem to the valve in the butt casting of the torch. When the button is pressed downward, the cutting jet is turned on. It may be latched down by pressing the button forward with the thumb when a long cut is to be made. It may be quickly released by moving the button backward and allowing it to rise to its original position when the valve will be closed.

Lighting the Torch

The cutting torch should be lighted in the following manner: Both oxygen and acetylene preheating valves and the cutting jet button should be in closed positions. An acetylene regulator should be connected to an acetylene cylinder or to a line from an acetylene generator, as heretofore described, and an oxygen cutting regulator to the oxygen cylinder. The oxygen cutting regulator is identically like an oxygen welding regulator except that the regulator nozzle is a little larger and the outlet pressure gauge is graduated to 300 pounds per square inch instead of 150 pounds per square inch as is often the case upon regulators used for both welding and cutting. The springs are usually a little heavier than in a welding regulator, because of the higher pressures required.

Oxygen and acetylene hose lines are connected from each regulator respectively to the oxygen and acetylene inlets of the cutting torch. It should be remembered that both oxygen and acetylene regulator adjusting screws should be fully released before the cylinder valves are opened. The adjusting screws of the regulators are then turned to the right until proper pressures show upon the outlet gauges of the regulators. These may be determined by consulting the manufacturer's chart for the equipment which is in use. Pressures vary with different makes of cutting torches and to obtain the best results, the recommendations of each manufacturer should be carefully carried out. The next step is to open the acetylene valve on the torch and light the acetylene at the tip of the torch. Open the oxygen valve and it will be noted that the yellow, smoky flame of acetylene burning alone will change to a luminous cone at each of the preheating jets. These should be adjusted until neutral in character; there will then be several small welding flames called preheating flames issuing from the tip of the torch. The button lever controlling the oxygen cutting jet should then be pressed downward and a further adjustment of the acetylene valve made until the preheating flames have well defined cones when the cutting jet is turned on. If the pressure of the cutting jet is not quite enough with the jet turned on, a little adjustment at the oxygen cutting regulator will increase the pressure as may be desired.

How to Cut with the Torch

The button of the cutting valve should now be released and the preheating flames at the tip of the torch applied to the edge of the piece to be cut. Whether the piece is rectangular or round makes no difference except that the rectangular piece is an easier piece to cut than a round shaft or a pipe. Wherever possible the cut should be started at the edge as stated above, and no attempt should be made to punch a hole downward through the center of the piece, unless the work is such that no other procedure is possible. It will be readily understood why this is so for the following reasons: When the torch is applied to the edge of a piece of metal, the molten oxide and slag are carried straight down along the edge and blown out at the bottom. If cutting is done over the hole in the table, shown in Fig. 7, the oxide flows down into the box under the table and sparks and flying particles of slag will not set fire to anything in the room or to the operator's clothes.

If, on the other hand, an attempt is made to burn a hole with the torch directly in the middle of a piece of steel, the oxide and sparks will fly upward against the tip of the torch and lodge on the operator's clothing or possibly in his hair. These sparks may fly where they will do damage and if one of them accidentally drops down into the operator's shoe or down his neck, he will have to stop cutting until the offending spark has been removed.

The operator should, therefore, direct the preheating flames, as indicated in Figures 3 and 4, against the side of the piece to be cut. As soon as this spot is red hot, the cutting jet may be turned on and the cutting action will immediately start. Care should be taken to see that the flow of the slag is clean and straight downward through the metal and as the cut progresses the flow of the oxide through the slot being cut should be watched very carefully. The torch should progress along the line to be cut at a speed just sufficient to allow combustion to take place clear through the section as the torch progresses. Cutting is very easy and after a little practice the operator will find that he can cut ordinary thicknesses of metal without any trouble and accomplish a thoroughly smooth job. When a straight line is to be cut across a piece of steel plate, it will be found very convenient to lay a piece of steel bar across the plate and slide the torch along the bar as the cut is being made. This steadies the torch and enables the cut to be made straight and smooth.

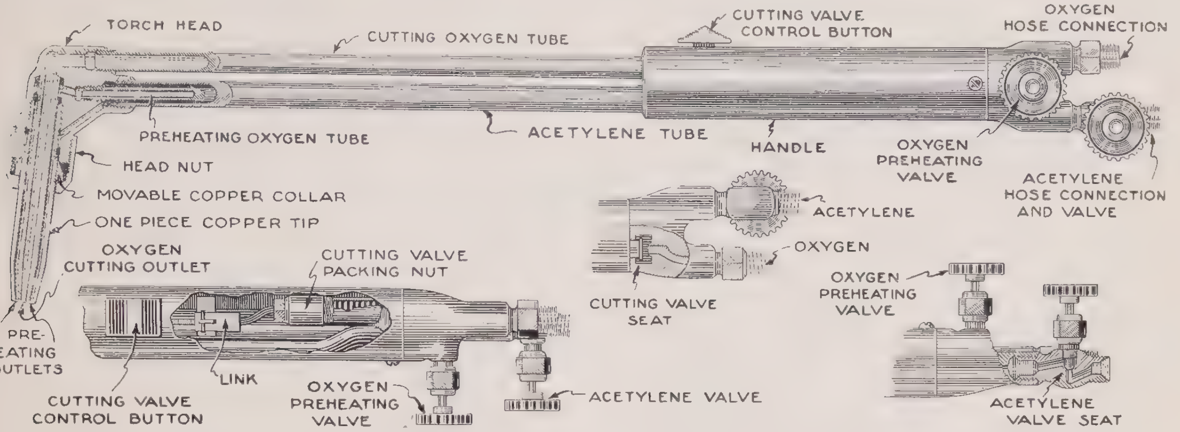

TORCH HEAD
CUTTING OXYGEN TUBE
CUTTING VALVE CONTROL BUTTON
OXYGEN HOSE CONNECTION
PREHEATING OXYGEN TUBE
ACETYLENE TUBE
HANDLE
OXYGEN PREHEATING VALVE
ACETYLENE HOSE CONNECTION AND VALVE
HEAD NUT
MOVABLE COPPER COLLAR
ONE PIECE COPPER TIP
ACETYLENE
OXYGEN
OXYGEN CUTTING OUTLET
CUTTING VALVE PACKING NUT
CUTTING VALVE SEAT
OXYGEN PREHEATING VALVE
PRE-HEATING OUTLETS
LINK
OXYGEN PREHEATING VALVE
ACETYLENE VALVE
CUTTING VALVE CONTROL BUTTON
ACETYLENE VALVE SEAT

Figure 8—Sectional View of a Cutting Torch. Cutting Torches Have Both Oxygen and Acetylene Valves, Controlling the Preheating Flames at the Tip of the Torch. They also have an Additional Valve Controlled by a Lever or Button which Shuts off and Turns on the Cutting Jet of Pure Oxygen Issuing From a Hole in the Tip Located Centrally Between the Preheating Flames.

Combination Welding and Cutting Torches

Where cutting is the only work to be done with the torch, as is the case in a steel foundry where steel risers are cut from castings, or in many other classes of work where in that particular department cutting only is accomplished, a cutting torch will be found more useful for the purpose than a combination welding and cutting torch as shown in Fig. 3. There are many cases, however, where a welder with but one outfit finds it necessary both to cut and weld. Under these circumstances a combination welding and cutting torch is very much more convenient than two torches, one a separate welding torch and the other a separate cutting torch, and is considerably less expensive. In Fig. 3 such a combination is shown. The welding tip is screwed out of the handle, still attached to the lines of hose, and a cutting assembly is screwed into the handle in place of the welding tip. Adjustments are similar to those described for the cutting torch and in all other respects the action is the same.

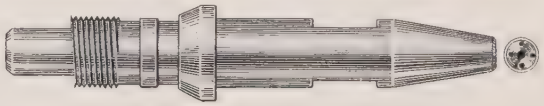


Figure 9—View of a Cutting Tip. The End View of the Tip is Shown Particularly to Indicate the Relative Position of the Cutting Jet of Pure Oxygen and the Four Ports where the Preheating Flames Burn. Some Tips are Made with Three Preheating Holes, While Others are Made with Five or Six Holes, Depending upon the Make of the Tip and the Particular Design.

Steel Not Affected By Cutting

One of the questions which is often asked about the cutting of steel is whether the steel adjacent the cut surface is chemically changed by the action of the oxygen jet. When a cut is smoothly made there is no effect upon the steel immediately adjacent the cut, except that it has been somewhat annealed, as would be the case if heat were applied to a piece of steel and it were allowed to slowly cool. It is important, however, that all cutting, particularly upon structural steel, be kept as smooth and as free from irregular projections as possible. There is a great deal of structural steel cutting carried on today, and an examination of any fabricated steel structure, like a bridge truss, or the girders and columns which make up a steel building will show that many brackets of all kinds are cut with the oxy-acetylene torch and that the structural steel members themselves are cut at the end to suit the type of bracket required at the point where they are joined to other members.

This cutting is all clean, smooth work. When the cut is roughly made in structural steel and there are a number of irregular, jagged projections along the line of cut, each one of these projections is apt to be the beginning of a possible crack which may take place if the steel is subjected to a heavy strain. A crack will not start along a smooth, straight edge as quickly as it will if the surface is irregular and nicked by the torch. For this reason, in cutting structural steel it is always desirable to use a straight bar or a similar guide so that the line of cut may be smooth and regular. An illustration of a smooth cut is shown in Fig. 6. The surface of this cut was actually smoother than would be the case if the cut had been made with a saw. The photograph is slightly enlarged and for this reason the lines of cutting made by the oxygen seem to be deeper than they actually are. In this illustration the cutting torch was moved too rapidly along the surface to permit the combustion of the steel to progress vertically downward through the piece at the same rapidity as the forward movement of the torch. If the speed at the torch and the progress of combustion of the steel through the plate had been correctly balanced, the lines of cut would be vertical lines instead of curved lines extending in the direction from which the cut was made.

Cutting Dies and Cams

A surface like that shown in Fig. 6 can be machined slightly and if the plate is made of tool steel, the edge can be made into a cutting edge. A piece of steel thus formed and afterwards heat-treated will make a die or a cam of any shape desired. There are a great many dies, cams and other irregular pieces of steel which are cut with the oxy-acetylene torch and utilized for many purposes. Such work usually requires a machine which automatically guides the torch around the line to be cut and in such instances high carbon steel is usually preheated to a black heat before cutting is started. This produces a smoother cut than would otherwise be possible.

Acetylene Generators

Mention has been made heretofore in these lessons of acetylene generators, but a detailed description of them has not as yet been given. A generator is a machine which automatically feeds carbide into water, thereby producing acetylene and storing a small quantity of it ready for use at the torch. It is always better practice not to store too much acetylene in the free state where welding and cutting are being carried on, and for this reason the storage capacity of the generator is made as small as possible. The generator itself is made automatic so that when the torch is turned on the machine immediately begins to feed carbide into the water and when the torch is turned off feeding automatically stops. Generators are generally divided into two classes, those producing acetylene under a pressure of less than one pound, called low pressure generators, and those producing acetylene under a pressure of more than one pound, called medium pressure generators. As this entire discussion of equipment is based upon torches of the medium pressure type, this lesson will be entirely confined to generators of this type, that is those delivering acetylene at a pressure greater than one pound and not in excess of fifteen pounds.

Medium Pressure Generators

In generators of this type the usual pressure at which the machine is set to operate is about twelve pounds. This pressure may be changed by the operator, but for most work it will be found satisfactory. The carbide feeding mechanism will operate very accurately; many are set to start at a pressure of nine and seven-eighths pounds and to stop at a pressure of ten pounds. There is, however, a certain amount of after generation caused by the complete disintegration of the lumps of carbide which have been dropped into the water by the feeding mechanism. This increases the pressure somewhat after the feeding mechanism has stopped feeding carbide.

There are very well defined rules and regulations covering the design and manufacture of acetylene generators which have been established by the Underwriters' Laboratories of Chicago, an institution built and maintained by the National Board of Fire Underwriters. This Board was organized and is controlled by the fire insurance companies of the United States and Canada. Generators which are constructed exactly in compliance with all of the regulations of the Underwriters' Laboratories and have been tested and passed by them are known as "Listed Generators" and are included in a list published by the Laboratories which is available to those interested. There are other machines upon the market which are constructed in principle in accordance with the requirements of the laboratories but do not include every required device and hence are not listed in the approved list.

These machines are generally known as unapproved machines and are, of course, less expensive to construct than those of the approved type. In most cases they comply in water and carbide capacity with the Underwriters' requirements if not in other details.

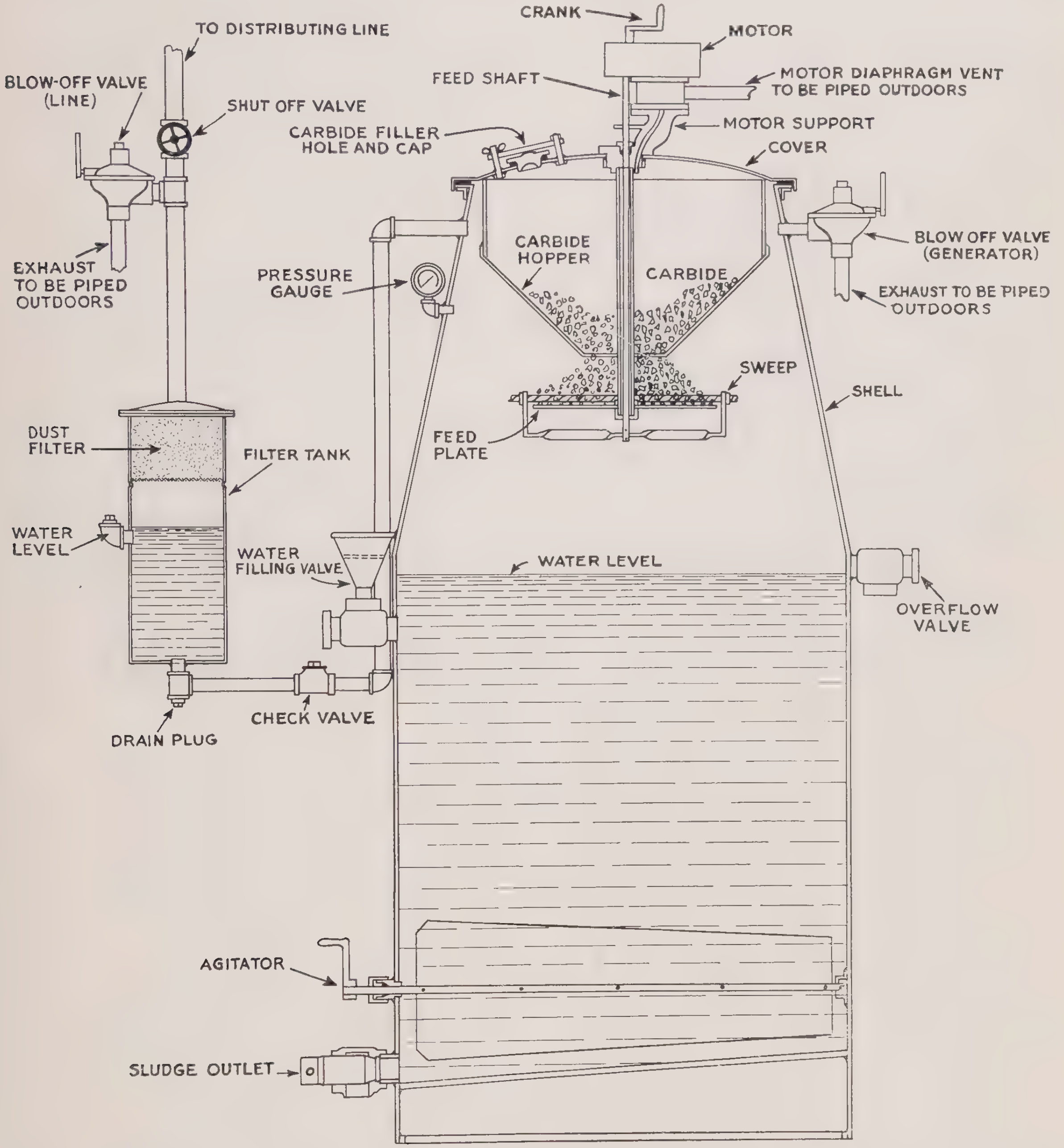

CRANK
TO DISTRIBUTING LINE
MOTOR
BLOW-OFF VALVE (LINE)
FEED SHAFT
MOTOR DIAPHRAGM VENT TO BE PIPED OUTDOORS
SHUT OFF VALVE
MOTOR SUPPORT
CARBIDE FILLER HOLE AND CAP
COVER
CARBIDE HOPPER
BLOW OFF VALVE (GENERATOR)
EXHAUST TO BE PIPED OUTDOORS
PRESSURE GAUGE
CARBIDE
EXHAUST TO BE PIPED OUTDOORS
SWEEP
SHELL
DUST FILTER
FEED PLATE
FILTER TANK
WATER LEVEL
WATER FILLING VALVE
WATER LEVEL
OVERFLOW VALVE
CHECK VALVE
DRAIN PLUG
AGITATOR
SLUDGE OUTLET

Figure 10—Diagrammatic Sectional View of an Acetylene Generator. The Interlocking Rods and Levers which Make It Impossible to Open the Carbide Flling Cap in the Top of the Generator Without Releasing the Blow-off Valve and Locking the Motor are not Shown. These are Required by the Underwriters' Laboratories upon Approved Machines and Prevent the Removal of the Carbide Filling Cap While there is Pressure Within the Machine. They also Prevent the Motor from Feeding Carbide into the Bottom of the Generator During Charging when there is No Water In It.

Some of the most important of the principles set forth by the Laboratories are as follows and practically fix the dimensions of both the generator and the hopper. For every pound of carbide contained in the hopper of the machine there must be one gallon of water. This requirement prevents overheating of the water. Therefore, in a fifty pound carbide capacity machine there must be sufficient space up to the overflow pipe for fifty gallons of water. From the carbide feeding plate to the top of the water there must not be less than ten inches. These general regulations it will be noted govern the approximate size, both in diameter and height of the machine. There are further regulations of the Underwriters which are important in the operation of generators. One of these is the requirement that acetylene shall not be withdrawn from a generator faster than its rated capacity as shown on the generator name plate. Some generators receive a higher rating than others. This is determined by the Underwriters' Laboratories, Inc. This is usually provided for by installing a generator of sufficient capacity to supply the maximum requirement of acetylene. Faster generation than this results in overheating the water and causing impurities in the acetylene.

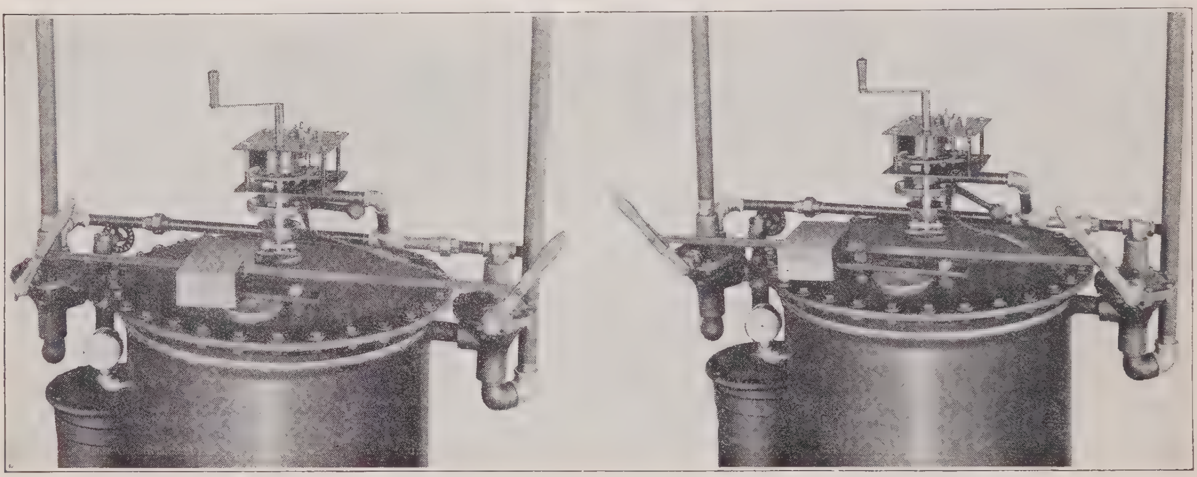


Figure 11. These Photographs Show the Top of a Generator, the Two Blow Off Valves and the Motor. The Photograph to the Left Shows the Guard Attached to the Rod Connecting the Blow Off Valve Levers, in Position Over the Thumb Screw Which Releases the Bar Across the Carbide Filling Opening. This is the Operating Position of the Machine and the Chain Holds the Weight Lever Under the Motor in a Position in Which the Motor Can Operate. In the Right Hand Photograph, the Levers of the Blow Off Valves Have Been Moved to the Left and the Guard Removed from Its Position Over the Thumb Screw of the Carbide Filling Opening. The Chain Has Also Been Released and the Weight Lever Has Dropped to the Top of the Generator Forcing the Other End of This Lever Upward and Locking the Motor. Therefore, When the Levers Are in This Position the Motor Cannot Be Run, But the Carbide Filling Opening Can Be Opened. At the Same Time Both of the Blow Off Valves Have Been Opened so That Pressure Within the Generator Has Been Released. These Are the Only Inter-locking Devices Necessary for This Type of Machine.

A sectional view of an acetylene generator is shown in Fig. 10. At the extreme top of the machine is a spring motor. There are machines upon the market operating in the same general manner with a motor driven by a weight or a diaphragm type feed (see page 57, figure 11). In the machine shown in Fig. 10 there is a pressure diaphragm directly under the motor, the movement of which operates a lever in turn operating a brake upon a disc. The spring of the motor is very powerful, but the braking disc just mentioned is geared upward in speed by a series of small gear wheels, until a very slight movement of the brake will stop it, or release it, as the case may be.

How Generators Operate

The main shaft of the machine, revolved by the spring motor, extends downward through a pipe to a cross member revolving directly under the feed plate of the machine which is in a fixed or stationary position. The cross member revolves a sweep, made of asbestos rope, which moves in a horizontal circle directly over the feed disc or plate. Carbide is placed in the hopper until the hopper is full. It flows out of the bottom of the hopper and comes to rest on the stationary feed plate. When the motor is started the sweep revolves and sweeps or forces off the feed plate a few lumps of carbide which fall down into the water. Acetylene is thus produced and the pressure within the machine increases until it overcomes the spring pressure against the diaphragm directly under the motor and stops the motor. As the pressure is decreased by consumption of the gas at the torch, the motor is again started and more carbide is swept off the stationary disc down into the water. This movement of the sweep and the feeding of the carbide are, therefore, automatically started and stopped by the opening or the closing of the torch valve.

It should be remembered that Fig. 10 is a diagrammatic view with the important parts of the generator spread out to show how they operate and what the details are for. In the top of the hopper there is an opening through which the carbide hopper is filled. This is closed by a cap and a rubber gasket held in place by a bar clamped by two bolts, across the opening. In the side of the machine there is a water filling funnel and an overflow valve, and in the bottom of the generator a sludge or residuum outlet. There is also an agitator operated by a handle on the outside of the generator, immediately over the residuum outlet in the bottom of the machine. The residuum from the chemical reaction taking place between the carbide and the water and consisting principally of slaked lime collects in the bottom of the machine. This residuum would not flow freely from the outlet if it were not for turning of the agitator.

Flash Back Check and Filter

To the left of the generator in Fig. 10 is shown the flash-back check and filter tank in section. The flash-back check is in reality a submerged check valve, or in other words a check valve under water, preventing the backward flow of oxygen and acetylene or of a flame into the generator. The small tank is filled with water to the proper level by removing the plug on the side and filling with water until the tank is filled to the opening, thus submerging the check valve as the water rises in the pipe leading to the generator to the same elevation as in the tank. It is always very important that this tank be filled with water to its proper level, because it is the main protection of the generator from a flash-back which might be caused in the pipe lines to the torches.

In the upper part of the flash-back check and filter tank, there is shown a filter consisting of a perforated partition over which is placed a quantity of hair felt or mineral wool. The gas passes upward through this filter which to a large extent prevents moisture and lime particles from passing upward with the gas. The flash-back tank aside from operating as a flash-back check, also is essentially a scrubber for the gas, as it bubbles upward through the water. Washing of the gas in this manner is beneficial to it and assists in removing particles of sludge.

Blow Off Valves

Attached to the outlet pipe from the flash-back check and filter tank is a blow-off valve set to blow off at fifteen pounds per square inch. The outlet of this blow-off valve is connected by a blow-off pipe line upward through the roof, ending in a return bend. There is another blow-off attached to the generator near the upper part of the hopper which is also set to blow at fifteen pounds per square inch and is connected by a separate blow-off line to the outside air. The blow-off pipes attached to the outlets of these two valves must always extend to the outside air separately and must not be connected together. Both of these blow-offs are connected by a rod to an auxiliary cover plate over the carbide filling opening in the top of the generator. This rod and cover are a part of the interlocking devices, not shown in any of the illustrations, except Fig. 11, which prevent the opening of the carbide filling cap without moving the cover to one side thus automatically raising the seat of each of the blow-off valves. This general device releases the pressure within the machine and at the same time through a separate device locks the motor so that no carbide can be fed into the lower part of the generator. When this is accomplished, the sludge outlet may be opened to drain the sludge out of the generator and the water filling valve opened to admit fresh water after the sludge has been removed. Carbide may then be filled into the hopper, the top replaced and fastened into position, but before the machine can again be placed in operation it is necessary to move the auxiliary cover over the carbide filling opening which automatically closes the blow-off valves and disengages the motor lock.

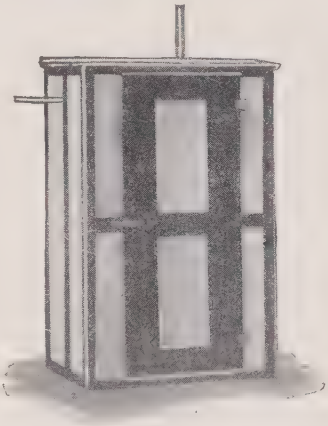


Figure 12—Photograph Showing a Generator Hot Box. This is an Insulated Box in Which a Generator Can Be Placed to Prevent Freezing in Cold Weather. Details of this Box are Given in Fig. 13.

Carbide Sludge

The sludge or residuum, as it is sometimes called, which is drawn from the generator each time the machine is filled with carbide is wet, slaked lime. It makes excellent fertilizer, good white-wash, and fine plaster. An analysis of dried sludge, furnished by a large manufacturer of compressed acetylene is:

Calcium Oxide	70.97%
Magnesium Oxide	Trace
Combined Water	23.69%
Carbon Dioxide	1.03%
Iron and Aluminum Oxides	1.55%
Silica and Acid Insoluble	2.76%

A good formula for making outside whitewash with carbide sludge is given as follows: The carbide sludge and water should be mixed to the desired consistency of the whitewash and eight tablespoonfuls of alum and four tablespoonfuls of salt added for each gallon of the whitewash liquid. Inside whitewash not exposed to rain can be made by adding one-half pint of glue to one gallon of whitewash made by mixing the carbide sludge with water to the desired thickness. Whitewash made in this manner is excellent for the interior of chicken-houses and other poultry buildings. It will kill germs and give a degree of cleanliness which is beneficial to the fowl.

While carbide sludge is not a fertilizer in the strict sense of the word, it will help to correct soil acidity and meet the lime requirements of the soil and of plants. Carbide sludge is a good liming material for the garden and for lawns. As it carries small traces of sulphur and phosphorus, it is even better than ordinary slaked lime as an insecticide and mould killer. The sludge is useful for lime washing of trees and bushes to destroy insects' eggs and parasite larvae and the mosses and lichens which often cover them.

The generator in a hot box cannot be left without operating for any great length of time with the anticipation that it will not freeze, but if the generator must be used outdoors, or in a large, cold building in winter, the hot box will materially assist in preventing freezing of the machine. Fig. 13 is a sketch showing the details of construction of a generator hot box. A blue print giving dimensions and complete details of this hot box can be obtained if desired. It is useful in a scrap yard and can be installed in many places where it is impossible to heat a room of larger size with steam or hot water heat.

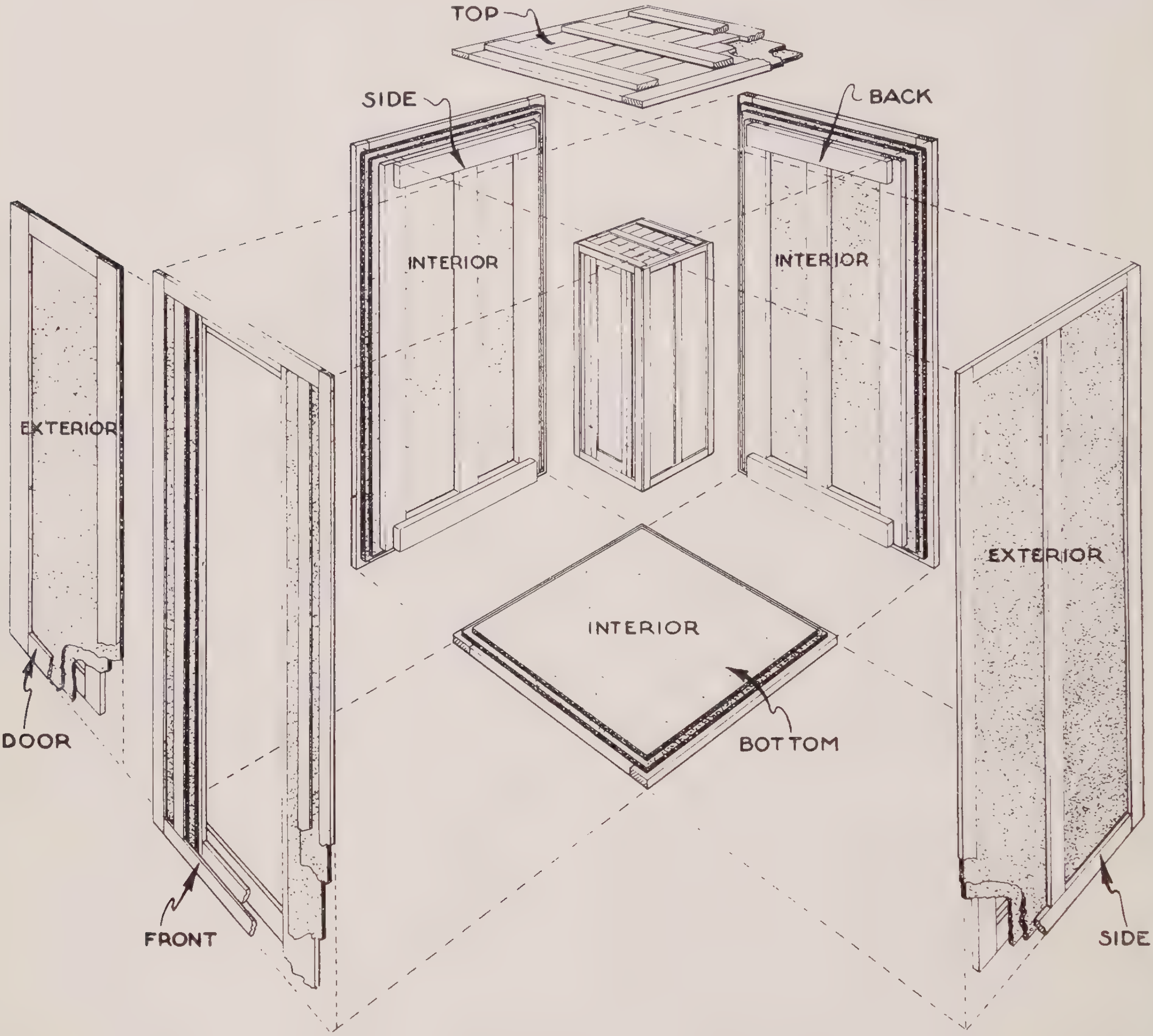


Figure 13—Sketch Showing the Details of a Generator Hot Box. It Is Constructed of Wood, as shown, With Two Thicknesses of Insulating Board. Detailed Directions and Dimensions for Making a Box of This Type Can Be Procured from the Publishers.

Generator Houses

Generator houses may be constructed in a very simple manner where a small generator is to be installed in a small shop. In a large industrial plant, they may be quite elaborate, depending entirely upon the number of generators installed and the service requirements of these machines. The smallest type of generator house is called a "Generator Hot Box" and is illustrated in Fig. 12. This is an insulated box, made of boards and insulated with two layers of Insulite, Celotex, or similar material. It is made to fit the generator as closely as possible, so that there will be little waste airspace inside. While the generator is in operation it keeps warm and will not freeze, and this warmth is kept within the hot box by its insulated construction.

Of course, the ideal way to install a generator is in a separate room, heated with either hot water or steam heat, or in a separate house also heated and constructed for the purpose. The details of the room or the building depend entirely upon the requirements of the individual case, and the shop or the industrial plant where the generators are to be used. The garage owner, for instance, having a good building, well heated, might find it convenient to build a small generator room of hollow tile or brick in one corner of the building. On the other hand, the operator of a frame blacksmith shop might build a lean-to immediately outside the main building or might install a generator in a separate room partitioned off with two by four posts and corrugated iron, on the inside of which plasterboard or Insulite could be used. In some instances, of course, the generator is used and installed in the same room where the work is carried on, but as far as possible it is good practice to install the machine in a permanent place properly protected from the cold.

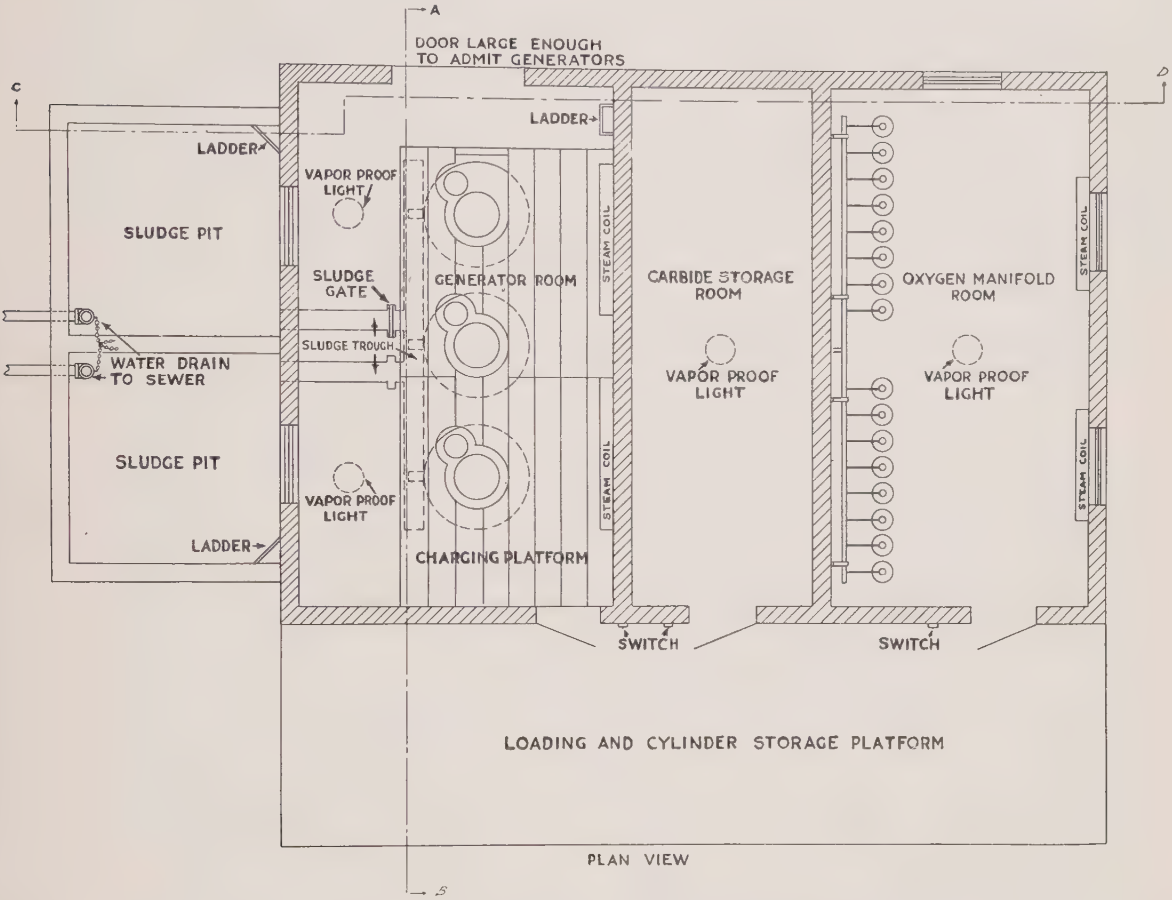

A
DOOR LARGE ENOUGH TO ADMIT GENERATORS
C
D
LADDER
LADDER
LADDER
VAPOR PROOF LIGHT
SLUDGE PIT
SLUDGE GATE
GENERATOR ROOM
STEAM COIL
CARBIDE STORAGE ROOM
OXYGEN MANIFOLD ROOM
STEAM COIL
SLUDGE TROUGH
WATER DRAIN TO SEWER
VAPOR PROOF LIGHT
VAPOR PROOF LIGHT
SLUDGE PIT
STEAM COIL
STEAM COIL
VAPOR PROOF LIGHT
CHARGING PLATFORM
SWITCH
SWITCH
LOADING AND CYLINDER STORAGE PLATFORM
PLAN VIEW
B

Figure 14—Plan of a Typical Gas House Used in Large Industrial Plants and in Railroad Shops. The House is Divided Into Three Rooms, one for the Oxygen Manifold, one for Carbide Storage, and the Generator Room the Floor of Which is Lower than the Other Rooms to Permit the Charging Platform to be on the Same Level as the Loading Platform Outside of the Building. Drums of Carbide may, Therefore, be Rolled out of the Carbide Storage Room to the Loading Platform and onto the Charging Platform of the Generator Room without Lifting.

Ventilation is always important. The hot box heretofore described is not ventilated because of the necessity for using all of the heat produced by generation to prevent freezing. Generator houses and rooms, however, should always be well ventilated to prevent the accumulation of acetylene in any quantity. Inflammable gases should never be allowed to collect in any confined space, and generator houses should be so constructed that, as far as possible, there will be no place where gas can collect. For this reason ventilators should be placed in the roof. Sludge pits particularly should always be placed outside of the building and never under it where slight after generation from the sludge might leak upwards through openings into the generator room and fill it with inflammable gas.

House for Industrial Plants and Railroads

In Figures 14, 15, 16 and 17 details are shown of a very convenient and practical acetylene generator house for an industrial plant or a railroad. This house is divided into three rooms, one an oxygen manifold room where the oxygen cylinders are stored and manifolded to the pipe lines leading to the welding and cutting stations about the plant. The middle room is for the storage of carbide and will hold approximately a carload. The generator room, to the left of the building, has the floor level below the general ground elevation about the building. It is constructed in this manner so that the charging platform surrounding the generators is at the same level as the carbide storage room and the loading platform. This arrangement eliminates the lifting of carbide to the top of the generator and carbide drums may be rolled from the carbide storage room to the platform and through the door of the generator room opening upon the charging platform. In this manner a great deal of labor is avoided and the charging of the generators becomes convenient and quick.

Two sludge pits are provided, one being used while the sludge is settling to the bottom in the other. Sludge can be run from the main sludge trough under the sludge outlets of the acetylene generators through two cross troughs to either one sludge pit or the other. The flow of the sludge is controlled by a simple board gate dropped into a slot in the concrete floor, thus closing off the trough to whichever pit is not in use. The outlet of each sludge pit drains to the sewer, but it will be noted that the stand pipe within the pit is mounted on a cast iron elbow, the thread of which is loose on the outlet pipe. For this reason, the end of the stand pipe can be raised or lowered and only the clear water drawn off from the top of the sludge and allowed to run into the sewer. The angle of both stand pipes and, therefore, the elevation of the upper end is controlled by chains which are hooked over a steel pin in the top of the wall of the pit. As the sludge collects in the bottom of the pit, it is removed from time to time, loaded into a truck and delivered wherever there is a market or a use for it.

A generator house of this type can be built with a concrete foundation, hollow tile or brick walls, or the walls can be made of a steel frame covered on the outside with corrugated iron and on the inside with Insulite, plasterboard or some other sealing material. Plenty of light should be provided, with windows and doors opening onto the loading platform, or outside, and not from room to room. Electric switches should be placed on the outside of the building, electric wires carried in conduit to vapor-proof, gas-tight electric lights.

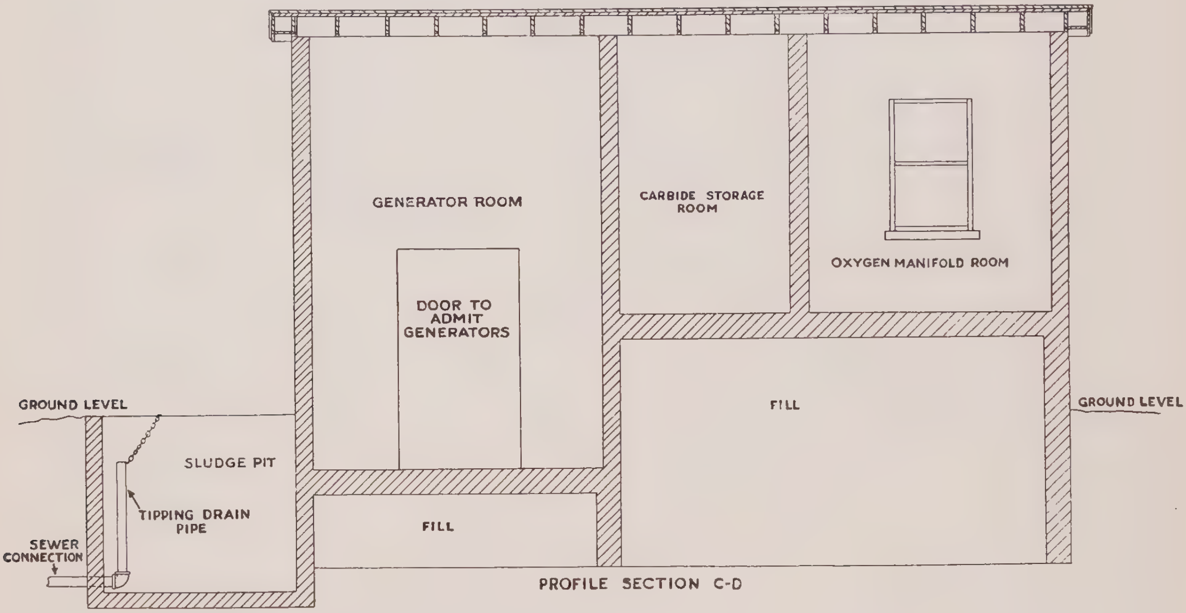


Figure 15—Profile Section C-D Through the Gas House Showing the Different Elevations of the Generator Room Floor and the Floors of the Carbide Storage Room and Oxygen Manifold Room. This Section also Shows the Tipping Stand Pipes Which Drain the Sludge Pits. In this Manner Clear Water can be Removed From the Top of the Sludge and the Sludge Itself Kept out of the Sewer.

Steam heating coils should be placed in the generator room and the oxygen manifold room, but no heat is necessary in the carbide storage room. A water line not less than one inch in diameter and preferably one and one-quarter inch should be run underground to the house and should rise through the floor of one corner of the generator room. Ventilators should be placed in the roof to assure proper ventilation of all rooms. The details of the oxygen manifold were fully covered in Lesson No. 3 and the details of the piping from the acetylene generators, including both the acetylene distributing lines and the vent pipes are shown in Fig. 17.

Water Filling Pipes and Sludge Outlets

In an acetylene generator house, or for that matter, wherever a generator is located permanently, it is important that water be available so that the generator may be filled conveniently and without any more labor than is necessary. In

Fig. 17 these water pipes are shown extending from the main water line entering the generator house to a point immediately over the filling funnel of the generator. There a valve is placed and by turning on the valve the water can be run directly into the funnel. Direct connections, such as the attaching of a pipe from the water line to the acetylene generator, should never be made, because in this event if the overflow valve were not open, the carbide hopper might be flooded if the water level rose above the normal water line within the machine.

The sludge outlet of a generator should never be directly connected to a pipe leading to the sludge pit, or outdoors in such manner that the operator cannot see that the sludge valve is tight and is not dripping. In some cases the sludge valve is so designed that a little grit or hard particle of carbide sludge might lodge under the valve. This would be true if a gate valve were used as a sludge outlet. If the operator is unable to see that this valve is not tight, the water within the generator might run out without his knowledge and under these conditions, if he should set the machine in operation without water in the generator, serious results might occur.

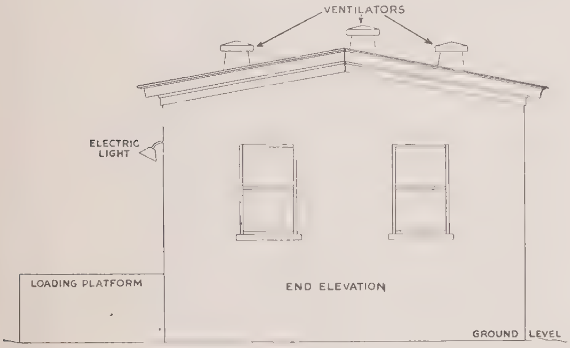


Figure 16--End Elevation of the Generator House Showing the Loading Platform Beside a Railroad Siding or a Driveway for Automobile Trucks.

Freezing of Generators

Acetylene generators should not be allowed to freeze any more than should an automobile, or the plumbing in a house or building. Freezing is bound to cause damage to the machine and if an attempt is made to operate the generator while it is frozen, the result may be serious. If a generator should freeze, however, the method of thawing it will depend entirely upon the local conditions. Hot water or steam, if available, are the best. An open flame of any kind should never be used. If the water within the acetylene generator becomes frozen, the cover, carbide hopper and motor should be entirely removed and the ice melted and removed from the inside of the generator. The inside of the machine should then be examined to see if any damage has occurred. If the generator is undamaged and all of the piping is clear, it should be filled with water to proper water level and the carbide hopper, top and motor replaced.

The filter tank and the flash-back check valve, see Fig. 10, are more apt to freeze than the generator itself, but these can be quickly thawed out by removing the drain plug in the bottom of the filter tank, the plug at the water level, and pouring hot water into the tank. Care must also be taken to see that the check valve and the pipe leading to the generator are entirely free of ice. Hot water and hot cloths will usually take care of this pipe, but it should be very carefully examined after it has been thawed out to see that it is not damaged. The best plan is to make provision for the generator so that it will not freeze. This can often be done by constructing a hot water coil extending into the generator room from a stove in the welding shop. The piping and the coil can be all welded and construction costs thus made as low as possible. Old pipe may be used and scrap sheet iron welded in the shape of a box for the expansion tank. A coal fire maintained in the welding shop over Sunday will thus keep the generator from freezing up.

Safety Precautions

Acetylene generators are safe in every respect when they are properly operated. Carelessness in operation, however, is inexcusable and there is no more reason for blowing up a generator than there is for blowing up a gas tank upon an automobile. Every generator explosion which has occurred has been caused either by the neglect or the lack of knowledge of those connected with it. Accidents almost never occur through fault of the machine itself if it is properly designed and constructed, and has been obtained from an experienced manufacturer of acetylene generators. *Home-made machines designed and constructed by someone lacking in generator experience should not be used.* The National Board of Fire Underwriters in their regulations for the installation and operation of acetylene generators set forth among others, certain important rules which should always be followed. These are very simple and may be stated as follows:

When charging a generator:

1. *Release the pressure within the machine through the opening provided.*
2. *Remove the sludge and wash out the generator with clear water and immediately fill it with clear water to the level of the overflow pipe. Be sure that the water does not come above this level.*
3. *See that the filter and flash-back check tank is filled with water to the proper level.*
4. *Fill the hopper with carbide. Never attempt to put carbide into the hopper until after the generator is properly filled with water.*
5. *Immediately remove the air mixture in the generator above the water level in accordance with the instruction card furnished by the manufacturer.*
6. *When generators are not in use water should be kept in the generator to the proper level if any carbide remains in the hopper.*
7. *Never set the blow-off valve or the motor so that the pressure in the generator is greater than fifteen pounds per square inch.*

8. *Never permit smoking, matches, or an open flame of any kind around generators.*
9. *If repairs are necessary requiring soldering or welding, remove the carbide hopper and drain out the water. Take the generator out of the generator room, wash out all sludge and completely fill the generator, the flash-back check and filter tank with water to force out all acetylene. Weld or solder with the generator filled with water.*

Always Fill Generators with Fresh Water

If the generator is always filled with fresh water every time a charge of carbide is placed in the hopper, there will be no possibility of the sludge within the machine becoming thick and heavy. Neglecting to change the water results in overheating of the generator and delivery of impure acetylene; such neglect if continued may endanger the generator. A very essential precaution is the maintenance of water up to the overflow valve in the generator when there is carbide in the hopper. The reason for this is quite simple. If a few lumps of carbide drop down into the water, acetylene is generated and the machine is operating normally. If, however, there is no water in the generator, the bottom of the machine is wet and carbide accidentally falls off the hopper down into the wet bottom, a lump of carbide in a little water will produce heat. In some instances the heat generated will be so great that the carbide may become red hot and if there is any air in the generator at the time an explosion may occur.

It is just as important that the water be maintained at its proper level and not be allowed to rise in the generator. If the hose were forced into the generator and the overflow valve closed, it might be possible to raise the water level so that it would flood the feed plate and wet the carbide. It might then recede, leaving the carbide on the plate wet, but not submerged in water, and thus generate sufficient heat to cause the carbide to become red hot, and in similar manner, if air were present in the right proportions, create an explosion. The operator who does either of these things, is utterly careless and is disregarding the principles of operation of an acetylene generator just as much as a locomotive engineer would do if he took an engine out on the line without any water in the boiler. Ordinary care of an acetylene generator means safety, and if it is properly taken care of, there is less hazard in its operation than there is in most of the daily occupations of the great majority of men.

Oxygen and Acetylene Pipe Lines in the Shop

It is essential that both acetylene and oxygen pipe lines about a shop be of sufficient diameter to deliver the required quantities of these gases. The smaller the diameter of the pipe the greater the frictional resistance to the flow of gas and hence the greater the loss in pressure. As the acetylene is under much lower pressure than oxygen in a pipe line, it is essential that particular attention be given to the size of the acetylene pipes. Theoretical figures almost always indicate that a pipe will discharge more gas with less loss of pressure than it normally will under practical conditions in a shop where a good many angles and turns are made in the pipe line. These turns create considerably more frictional resistance than would be the case were the line straight.

Furthermore, in an acetylene installation, because extensions of the line are made from time to time, the main line should be installed with this in mind, that in all probability more torches will be put in service requiring more gas. For this reason, the general rules governing the size of pipe leading from an acetylene generator, or from a number of them, are based upon experience. In practice larger pipe is actually used than is shown necessary by theoretical figures.

Acetylene Pipe Lines

For instance, in an installation like that indicated by the gas house where three, three hundred pound acetylene generators are required, the pipe manifold from the outlet of each generator to the main service line should be two inches in diameter and this two inch line should be led into the main shop or factory building.

In all probability at that point the pipe line would branch into two or three branches and these could be cut down in size to one and one-half inch pipe leading part way down the shop and then reduced to one and one-quarter or one inch pipe, depending upon the number of outlets leading from the main line. As a rule, these pipes are hung from the roof of the building or run along a crane girder with branch pipes leading to each station. These branch pipes may be one-half inch in diameter, ending in a valve and a special fitting to which a regulator may be attached. This arrangement is shown in Fig. 18.

Oxygen Pipe Lines

The main supply pipe from the oxygen manifold of such an installation should leave the manifold room and the gas house as a one and one-quarter inch pipe line. This would be reduced within the main building to one inch, as it branches down beside the acetylene lines in the building. Part way down the building it should be reduced to three-quarter inch and the downcoming pipes from the main line should be one-half inch, ending in a valve and a special fitting, for an oxygen regulator as shown in Fig. 18. Of course, in smaller installations the pipe sizes would be smaller, but the main line from a generator to several stations should never be as small as one-half inch.

If only one station is to be used and the generator is a fifty pound machine, a one-half inch pipe would ordinarily suffice, but if several stations are to be used and the machine is a one hundred pound machine or larger, the pipe should be increased until it has ample capacity to supply the number of stations required. The length of the pipe, of course, will have considerable bearing on the diameter and if a long line is to be supplied, the pipe must be larger in size.

For acetylene pipe lines, standard weight, black

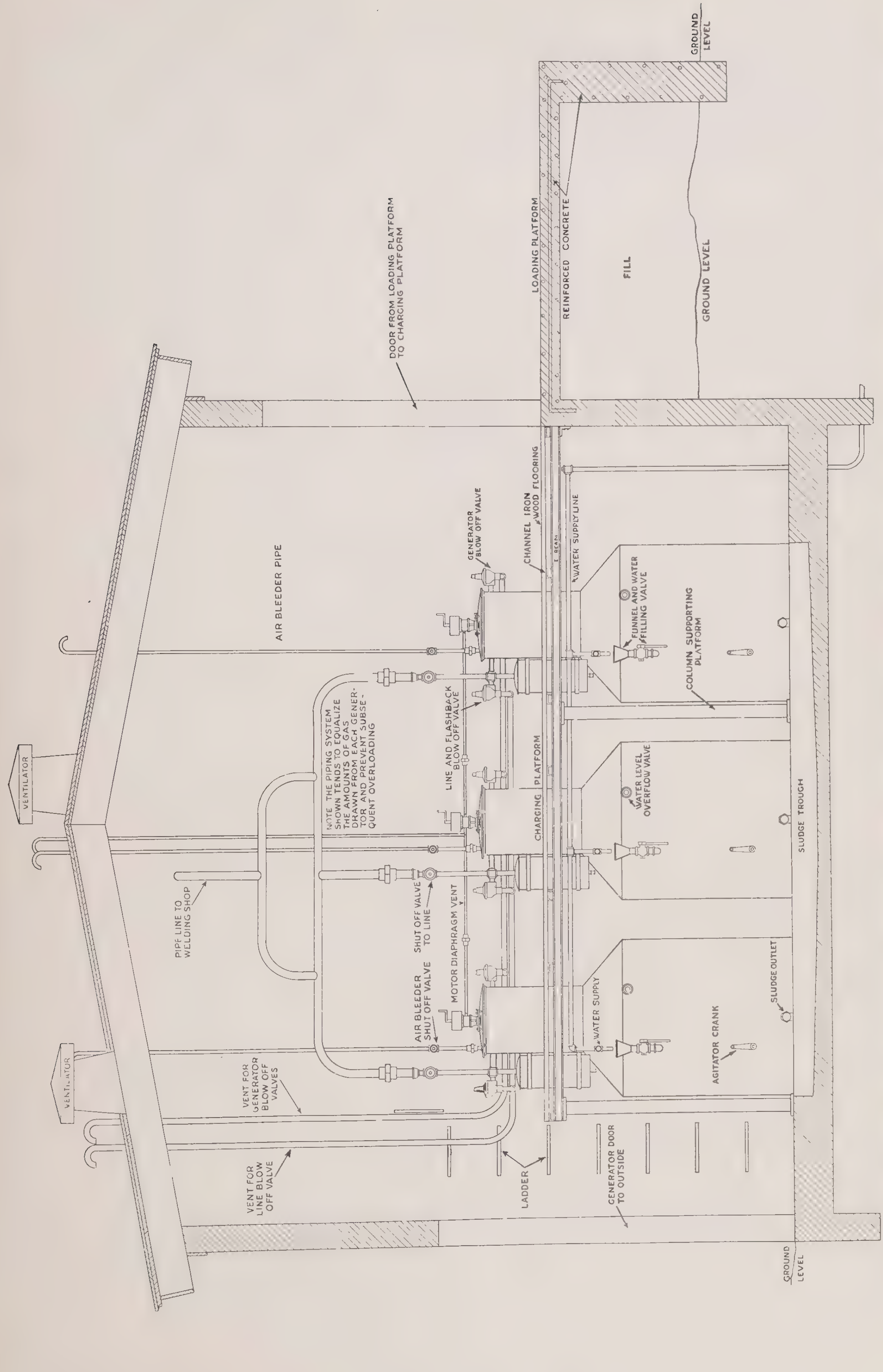

VENTILATOR
VENTILATOR
VENT FOR LINE BLOW OFF VALVE
VENT FOR GENERATOR BLOW OFF VALVES
PIPE LINE TO WELDING SHOP
AIR BLEEDER PIPE
NOTE THE PIPING SYSTEM SHOWN TENDS TO EQUALIZE THE AMOUNTS OF GAS DRAWN FROM EACH GENERATOR AND PREVENT SUBSEQUENT OVERLOADING
AIR BLEEDER SHUT OFF VALVE
SHUT OFF VALVE TO LINE
MOTOR DIAPHRAGM VENT
LINE AND FLASHBACK BLOW OFF VALVE
GENERATOR BLOW OFF VALVE
DOOR FROM LOADING PLATFORM TO CHARGING PLATFORM
LADDER
GENERATOR DOOR TO OUTSIDE
CHANNEL IRON
WOOD FLOORING
I BEAM
CHARGING PLATFORM
WATER SUPPLY LINE
WATER SUPPLY
LOADING PLATFORM
REINFORCED CONCRETE
FILL
GROUND LEVEL
GROUND LEVEL
GROUND LEVEL
FUNNEL AND WATER FILLING VALVE
WATER LEVEL OVERFLOW VALVE
COLUMN SUPPORTING PLATFORM
SLUDGE TROUGH
SLUDGE OUTLET
AGITATOR CRANK

Fig. 17—Sectional View A-B Through the Generator Room Showing the Location of the Generators in this Room with the Various Water, Vent and Bleeder Pipes From the Generators, and the Acetylene Distributing Manifold From the Generators to the Main Pipe Line Leading Out of the Building. This Manifold Helps to Equalize the Flow of Acetylene From the Generators When More Than one of Them are in use Simultaneously.

steel gas pipe may be used. Such lines should be welded if possible and all bends made with as large a radius as is convenient. The oxygen line on the other hand should be extra heavy and of black, wrought iron pipe with all joints welded if possible. Wrought iron pipe is specified for the oxygen line in preference to steel pipe, because wrought iron will last much longer than steel when subjected to an atmosphere of oxygen and extra heavy pipe is recommended because of the greater thickness of the wall.

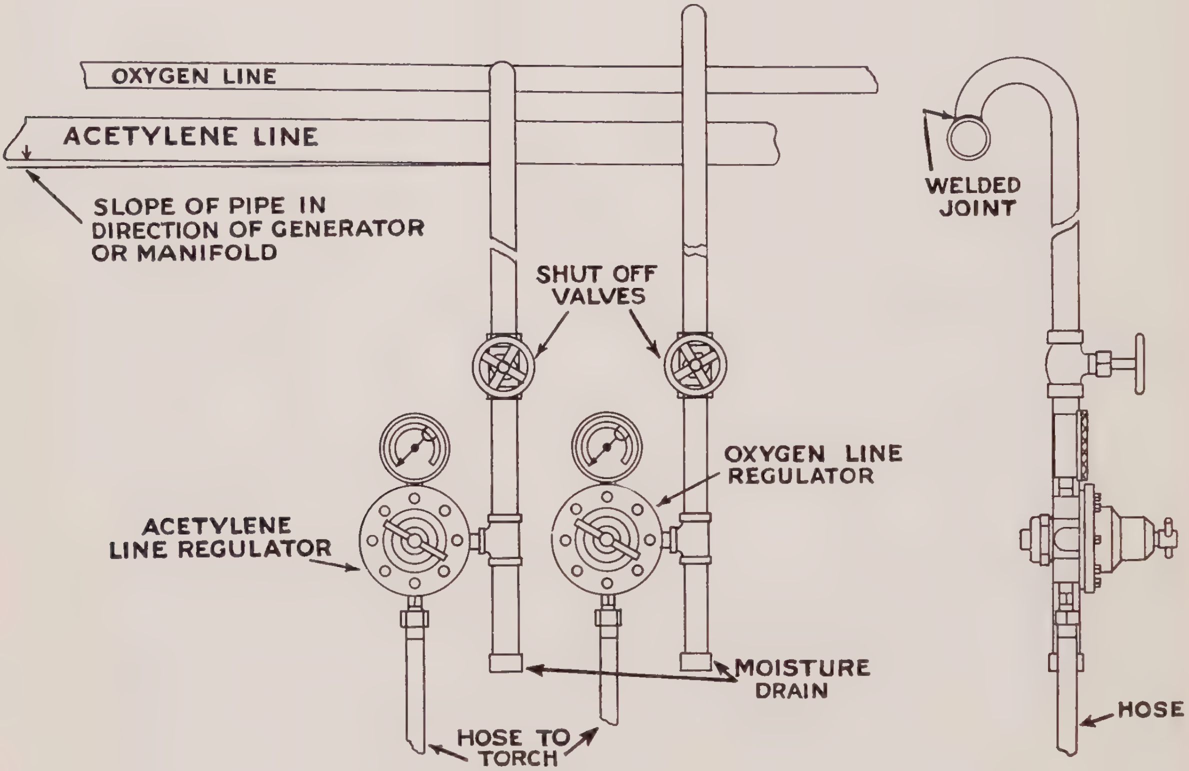


Figure 18—This is a Typical Station Outlet for Both Oxygen and Acetylene Pipe Lines From the Generator House. Stations for the Attachment of Oxygen and Acetylene Regulators are Placed at Convenient Points Around the Shop or Plant Where Welding or Cutting is to be Accomplished.

All oxygen pipe should be washed clean with hot water and washing soda before being erected. This is essential particularly where the pipe lengths are cut and threaded. Oxygen pipe must be absolutely free from oil or grease and a good way to be sure of the cleanliness of the pipe is to wash it in a strong, hot solution of washing soda and water, or, if necessary, a hot caustic solution.

Drainage of Pipe Lines

Both oxygen and acetylene pipe lines should pitch at least one-eighth of an inch to one foot and if possible one-quarter of an inch to one foot toward the lowest point in any one branch; a drip pot should be placed at this point. A very good drip pot can be easily made by inserting a welded nipple in the line and screwing a one-half inch globe valve to the end of the nipple. The drip pot is made of a piece of three inch pipe about twelve inches long with a circular plate and a one-half inch nipple welded in each end. One nipple is screwed into the valve on the pipe and an additional valve screwed on the opposite end of the drip pot. The drip pot, therefore, hangs vertically downward from the main pipe line at the lowest point in the line.

The upper valve is left open and the lower valve closed. Any water which may collect in the pipe will run down to the drip pot, and may be drained off at any time desired by closing the upper valve and opening the lower valve allowing the water to run into a bucket. If a pipe line is run underground it is very essential that a manhole be provided at a low point in the line and drip pots placed in the manhole. Underground pipe lines should be coated with asphalt paint before being buried in the ground.

Line Flash-Back Checks

In a long acetylene pipe line extending from building to building about a plant, it is often desirable to place one or two auxiliary flash-back checks at suitable points, where they will not freeze, to separate the line into several units and thus prevent the possibility of a flash-back extending from one building into another. Flash-backs into the line will not occur except through carelessness of the operators in leaving valves open, or neglect of the regulators, or the torch valves, so that they become leaky or faulty in their operation.

Under such circumstances it is possible to create a mixture of oxygen and acetylene in one line which may develop a flash-back. A line flash-back check prevents the extension of such a flash-back beyond the building and is constructed in almost the same manner as the generator flash-back check having a small tank and a submerged check valve. These checks should always be placed where they can be conveniently kept filled with water to the proper level and where they will not freeze. If it is impossible to place such a check where it will not freeze, it can be filled with kerosene or with a half and half mixture of glycerine and water.

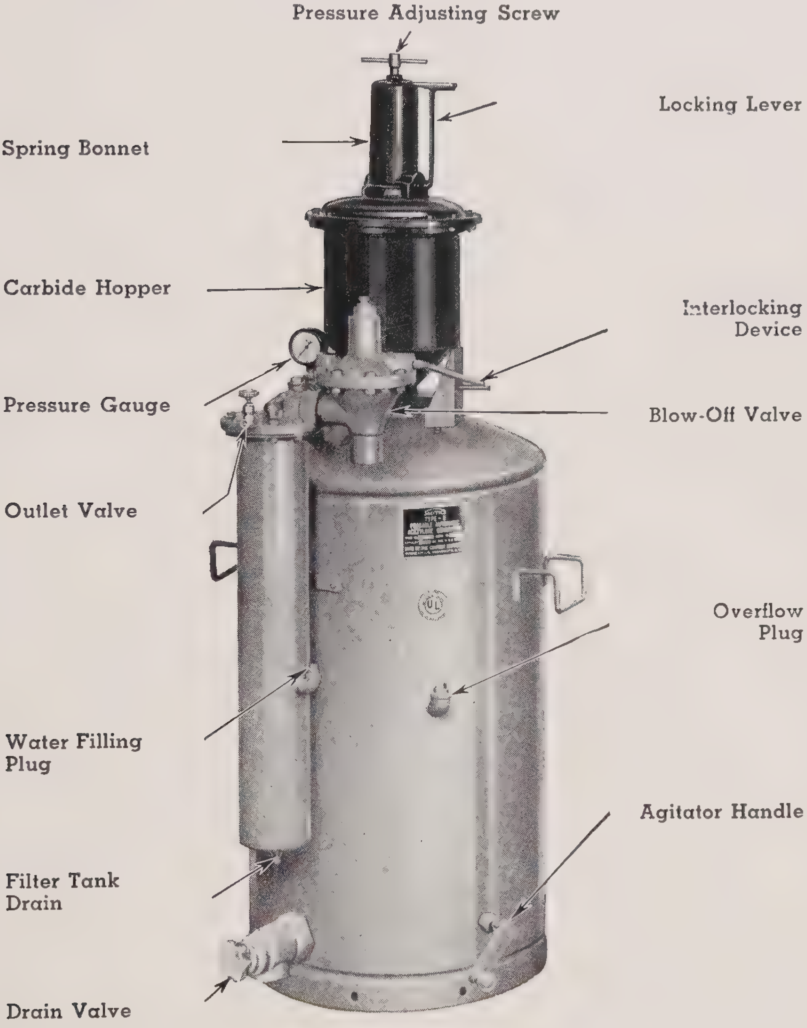

Pressure Adjusting Screw
Locking Lever
Spring Bonnet
Carbide Hopper
Interlocking Device
Pressure Gauge
Blow-Off Valve
Outlet Valve
Overflow Plug
Water Filling Plug
Agitator Handle
Filter Tank Drain
Drain Valve

Figure 19—View of a Portable Acetylene Generator using a Diaphragm Type Feed. Size 14 N. D. carbide is stored in the hopper in the upper part of the generator. As the diaphragm lowers (due to drop in pressure within the generator) a feed shaft is lowered which permits the fine grain carbide to feed into the water in the main chamber of the generator. As the pressure increases it raises the diaphragm and closes the feed opening.

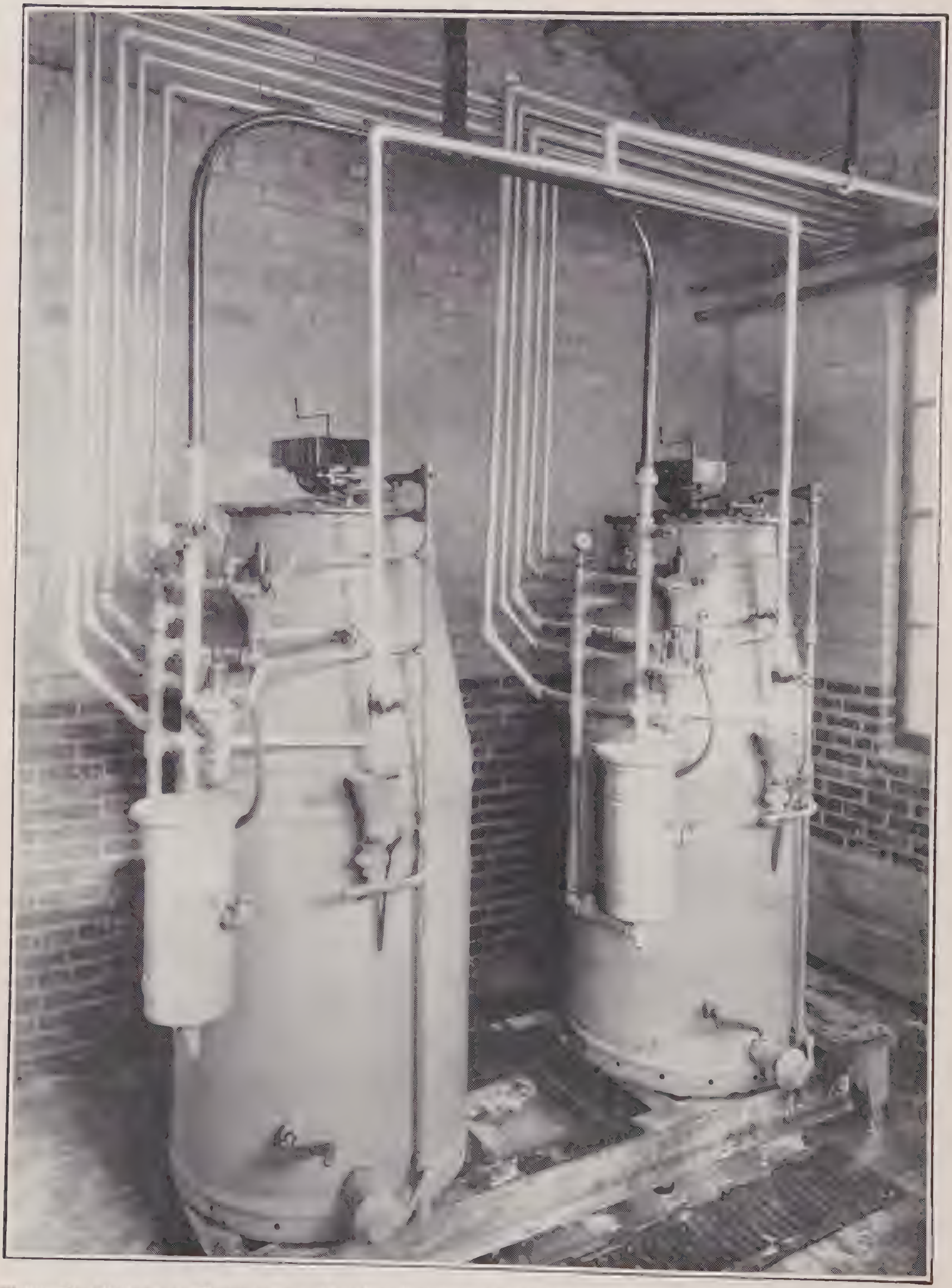


Figure 20—Photograph Showing Two Acetylene Generators Set Up in the Generator Room of the Gas House Shown Upon Page 60. This Is a Typical Installation and the Piping Is Clearly Illustrated. The Two Pipe Lines Showing Black in the Illustration and Having the Long Radius Bends are the Main Service Lines conveying Acetylene to the Shop, and to the Outside Welding and Cutting Stations Located Along the Track As Shown on Page 108.

Job Sheet No. 4

Vertical Welding by the Semicircular Movement Method
Oxy-Acetylene Cutting

The welding required for this lesson is identical with that described in Job Sheet No. 3, except that the work is done with the steel in a vertical instead of in a horizontal position. The equipment, welding rods and steel required are the same.

1. Set a piece of sheet steel one-eighth inch in thickness in a vertical position on some fire bricks on top of the welding table. The steel sheet should rest against some fire bricks so that it is as nearly vertical as possible.
2. Arrange a carbide can or a stool upon which to sit and hold the torch and the rod in the position shown in Fig. 1.
3. After lighting the torch, begin welding at the bottom of the sheet and continue making a bead with the semicircular movement method described in Lesson No. 3, upward along the surface of the sheet.
4. Practice again and again making vertical beads in this manner until proficient in vertical welding.
5. Set two pieces of one-eighth inch sheet steel on end in a vertical position resting against a fire brick.
6. Tack weld these pieces together at each end.
7. Weld the two pieces together, beginning at the bottom of the seam and continuing to the top, using the semicircular movement method and producing an even, smooth ripple weld.

Cutting

1. Attach oxygen and acetylene regulators respectively to oxygen and acetylene cylinders, or the acetylene regulator to the outlet from a generator if possible, and hose and a torch handle to the regulators, as described in Lesson No. 1.
2. Select a cutting assembly, or its equivalent, and screw it into the torch handle, being sure that the joint is tight. Close both torch valves.
3. Select a No. 1 cutting tip, or its equivalent, and screw the tip into the head of the torch, being sure that the tip is tight within the head and that the tip nut draws the slip ring tight against the end of the head.
4. Pressures recommended for the No. 1 tip for cutting steel ¼ inch in thickness are eight pounds for acetylene and eighteen pounds for oxygen. If another make of torch is in use consult the manufacturers' pressure chart.
5. Open the oxygen torch valve, the preheating valve of the cutting assembly, the lever cutting valve and set the oxygen regulator to eighteen pounds. Close the preheating valve upon the cutting assembly and the cutting valve, but leave the oxygen torch valve fully open.
6. Set the acetylene regulator at a pressure of eight pounds, open the acetylene torch valve and light the acetylene at the tip.
7. Open the preheating valve upon the cutting assembly and adjust the preheating flames at the tip of the torch until they are neutral in character.
8. Press down on the cutting lever of the assembly and make a further adjustment of the acetylene valve, with the cutting valve open, until the flames have clearly defined cones.
9. Apply the preheating flames to the edge of a piece of one-quarter inch steel plate, set so that its end projects over the hole in the cutting table.
10. Heat the edge of the plate until it is red hot.
11. Press down on the cutting lever of the cutting assembly, thus discharging the oxygen cutting jet against the extreme edge of the red hot metal. The cutting action will immediately begin and sparks and molten slag will flow from the bottom of the cut down into the box under the table.
12. Move the torch from the edge where the cut was started across the surface of the plate, holding the tip of the torch about five-sixteenths of an inch above the surface of the plate. Move the torch along the line to be cut only as fast as the combustion of the metal will progress. If the oxide and slag are driven vertically downward through the plate, the speed of cutting is about right. If there is a distinct lag and the slag and oxide are being driven backward away from the direction of cutting, the torch is moving too fast and the speed should be slowed down a little. The tip should be held vertically so that the cut will be projected vertically downward through the plate. If the torch is moved too rapidly across the plate and the cutting action will not penetrate clear through it, the cutting lever valve should be closed, the edge of the plate at the end of the slot already cut preheated and the cut again started by opening the cutting jet.

When shutting off the torch, close the acetylene torch valve first and then the oxygen valve. If the torch is not to be used for some time, shut off the cylinders and release the pressure in the regulators as described in Lesson No. 1.

A little practice will enable the student to cut with a fair degree of accuracy as cutting is not particularly difficult.

Questions:

1. When making a vertical weld, why does not the molten metal drop away from the weld and onto the table?
2. What is oxy-acetylene cutting?
3. Approximately how much oxygen will be required to make a cut eight feet long through a steel plate three inches in thickness, with a tip that makes a kerf three-eighths of an inch wide?
4. What is "magnetic oxide of iron"?
5. Why is there a difference between the theoretical and practical amounts of oxygen used in making a cut?
6. What is the difference between a welding tip and a cutting tip?
7. How is it possible to keep a piece of heavy steel at cutting heat when a cutting tip has such comparatively small flames?
8. What is the "cutting jet"?
9. How is it controlled?
10. When is it turned on?
11. Describe the manner in which a cutting torch is lighted and properly adjusted.
12. What is a combination welding and cutting torch?
13. What chemical changes occur in a piece of steel being cut by an oxy-acetylene torch?
14. What is the difference between a low pressure and medium pressure acetylene generator?
15. How much water must an "approved" generator contain for each pound of carbide used in one filling?
16. How many times in an eight hour day may a thirty pound generator be recharged?
17. Describe the operating and recharging of a medium pressure acetylene generator.
18. What is the purpose of the filter and flash-back check tank shown in Fig. 10?
19. What is a generator house?
20. Is there any danger connected with the freezing of the water in an acetylene generator?

Main Pipe Lines from Acetylene Generators to Station Outlets

Table Giving Approximate Size of Pipe,* in Inches, Recommended When the Number of Cubic Feet Per Hour Required and the Length of the Pipe Line Are Known

Cu. Ft. Per Hr.	*Length of Pipe Line in Feet*																			
Required	50	100	150	200	250	300	350	400	450	500	550	600	650	700	750	800	850	900	950	1000
25	¾	¾	¾	¾	¾	1	1	1	1	1	1¼	1¼	1¼	1¼	1¼	1½	1½	1½	1½	1½
50	¾	¾	¾	¾	¾	1	1	1	1	1	1¼	1¼	1¼	1¼	1¼	1½	1½	1½	1½	1½
75	¾	¾	¾	¾	¾	1	1	1	1	1	1¼	1¼	1¼	1¼	1¼	1½	1½	1½	1½	1½
100	1	1	1	1	1	1	1	1	1	1	1¼	1¼	1¼	1¼	1¼	1½	1½	1½	1½	1½
150	1	1	1	1	1	1	1	1	1	1	1¼	1¼	1¼	1¼	1¼	1½	1½	1½	1½	1½
200	1	1	1	1	1	1	1	1	1	1	1¼	1¼	1¼	1¼	1¼	1½	1½	1½	1½	1½
250	1	1	1	1	1	1	1	1	1	1	1¼	1¼	1¼	1¼	1¼	1½	1½	1½	1½	1½
300	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1½	1½	1½	1½	1½
350	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1½	1½	1½	1½	1½
400	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1½	1½	1½	1½	1½
450	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1½	1½	1½	1½	1½
500	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1¼	1½	1½	1½	1½	1½
550	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½
600	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½
650	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½
700	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½
750	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½	1½
800	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
850	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
900	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
950	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
1000	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

**These Pipe Sizes Are Based Upon a Delivery Pressure of Acetylene at the Generator of 12 Lbs. Per Sq. In.*

Delivery Capacity of Acetylene from Acetylene Generators

The Requirements of the National Board of Fire Underwriters Limit the Delivery of Acetylene from Generators to the Following Volumes:

Carbide Capacity of Acetylene Generator in Pounds	Cu. Ft. Delivered Per Hour	Carbide Capacity of Acetylene Generator in Pounds	Cu. Ft. Delivered Per Hour
30	30		
50	50	200	200
100	100	300	300

Lesson No. 5

Welding and Cutting Small Diameter Pipe
Use of Templets

THE welding of pipe naturally divides itself into two general fields, namely, the welding of small pipe and the welding of large pipe. The small pipe is ordinarily used for steam and hot water heating, for gas pipes and some plumbing pipes in residences and in the smaller schools or other public buildings. Smaller pipe may also be used in the larger buildings where the main pipe line and headers are of larger diameter, but where the branches and the extremities of the main line have been reduced to smaller diameters. The principal distinction between the fields is that the smaller pipe field lies more largely within buildings and the larger pipe field represents the long lines of pipe for conveying oil, natural gas, illuminating gas, etc., where the pipe line is of large diameter pipe and perhaps several hundred miles in length.

Lesson No. 5 will be confined entirely to the welding of smaller pipe, while Lesson No. 6 will consider the long pipe lines constituting the latter field. The welding of pipe in general offers an immense field for the oxy-acetylene process. With the cutting torch, pipe can be cut to any desired shape, thus making the preparation of the pipe for welding a very easy and quick performance. With the welding torch two lengths of pipe can be very quickly welded together, or a nipple or a branch may be welded to a main line pipe. Fittings, like elbows, and tees, can be made from pieces of pipe, welded together, and the great advantage of all of these joints is that they are not only gas and liquid tight, but have greater strength than the pipe itself.

As an illustration of the assurance with which some large jobs have been constructed, large pipe lines have been welded for many miles with certainty on the part of the engineers and officials in charge of the work, that when they were completed they would be strong and tight. One of these was a pipe line in the western oil country where ninety-three miles of completed line was tested with a water test of seven hundred and forty pounds per square inch. Only four defects were found in twenty-five thousand welds. One poor joint and three pin holes were the only leaks in the continuous length of eight-inch steel pipe. Each of the twenty-five thousand welds made in steel nearly nine-thirty-seconds inches in thickness was twenty-seven inches in length. There was, therefore, the equivalent of ten and one-half miles of continuous seam. Seven hundred and forty pounds per square inch is a much higher pressure than welding is ordinarily subjected to, and yet there were only four defects and these were repaired as quickly as found. Such results prove without question that good welders under competent supervision can produce uniform welds upon which absolute reliance may be placed.

For this reason, the oil, natural gas and city gas industries have standardized upon welded pipe for all high pressure pipe lines. Engineers in these fields very quickly recognized the great value of welding, and as they were largely in control of the methods which could be used for such construction, they were able to adapt the process to their requirements without the resistance commonly encountered in other fields. The result of a few early welded lines was so satisfactory and the performance of these lines so excellent that the process rapidly became universal wherever pipe lines were to be constructed. This was also true for steam conveying pipe lines about a manufacturing plant, or upon mining property. There again the restrictions to be met with were within the control of the engineers who planned the work.

In buildings, however, and other structures, subject to building codes, prepared and controlled by city or state officials and other public authorities, the adoption of the process was much slower, because the engineers were not as free to adopt the newer methods as they were in the other fields where welded pipe proved so useful. Furthermore, it was difficult to gain permission of public authorities to utilize a process about which they were not as well informed as they were upon the older processes then in use.

In recent years, however, welded pipe has become more and more common in the building trades until today it is being used for a larger number of the newer buildings all over the country, and the rate of its adoption in these fields is increasing very rapidly. The time will come in the course of a few years when all piping used for conveying steam and hot water for heating in buildings, refrigerating and sprinkler systems and gas pipe will be welded. Furthermore, a large proportion, if not all, of the plumbing piping will be welded.

The extent of this great field for welding can as yet hardly be realized and will not be fully comprehended until engineers, architects, contractors and owners become more familiar with the advantages of welded pipe and adapt it to meet their requirements.

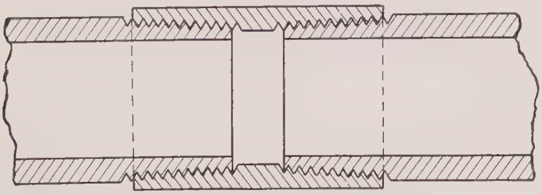


Figure 1—Sectional View of Pipe Joint Made with a Threaded Coupling. Note the Increased Thickness of the Pipe Walls Required Because of the Material Cut Away by the Threads. A Much Lighter Wall of Steel Could Be Used to Obtain the Same Strength if It Were Not for the Threads. The Weakest Part of the Pipe Joint is at the Bottom of the Thread at the End of the Coupling.

Threaded Pipe Joints

Threaded pipe joints are made by cutting a male thread upon the ends of pieces of pipe and female threads in couplings or fittings such as ells, tees, etc. For instance, two pieces of pipe are screwed into a coupling as shown in Fig. 1. The standard pipe thread used in the United States is known as Briggs American Standard, and is a tapered thread. In making up a joint similar to that shown in Fig. 1, white or red lead, or some other compound is placed upon the threads and they are screwed into the coupling until tight. The joint between the threads of the coupling and the threaded ends of the pipe is made up by the hardening of the lead. To hold any amount of pressure such a joint is obviously very unsatisfactory. Furthermore, the walls of the pipe must be considerably thicker than is actually required for the strength of the pipe itself, because a considerable proportion of them is cut away in making the thread.

Fig. 2 shows a butt weld made by bevelling the edges of two pieces of pipe at an angle of forty-five degrees with the end of the pipe and placing these two pieces of pipe together and welding the ends. The included angle between the bevelled ends is ninety degrees. The thickness of the wall of these pieces of pipe is the same as the standard pipe, shown in Fig. 1. The weld in Fig. 2 is built up to a thickness which is approximately twenty-five per cent greater than the thickness of the wall itself and for this reason the weld will develop the full strength of the pipe. In considering Figures Nos. 1 and 2, it is obvious that a welded joint made as shown in Fig. 2 will develop much more strength than a threaded joint, as shown in Fig. 1. In fact, the two should not be compared at all in strength, because if the pipe threaded as shown in Fig. 1 is strong enough to hold the pressure, then the joint shown in Fig. 2 has too much strength, in fact the whole structure is heavier than is necessary to hold the pressure.

In most instances the coupling does not screw clear up upon the thread, but will screw part way up, as shown at A in Fig. 3. As the thread is tapered, the thickness between the inside wall of the pipe and the bottom of the V thread at the point marked A, is the weakest part of the joint and is even weaker than it would be if the coupling was screwed up further on the thread. If the thickness of wall of pipe shown at the point A is sufficiently strong for the pressure within the pipe, including a fair allowance for safety, then it is only necessary to make the entire pipe of this thickness and, therefore, save a very considerable proportion of the steel which is needlessly wasted when threaded joints are used. This thickness of wall is shown at B, Fig. 3, with a welded joint which will develop the full strength of the wall of the pipe. For this reason, a pipe made with a welded joint, as shown at B, Fig. 3, will develop just as much strength as the heavier pipe with the threaded joint shown at A.

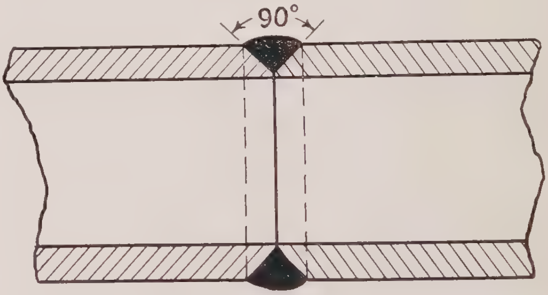


Figure 2—An Enlarged View of a Butt Welded Pipe Joint Made in Standard Pipe Having the Same Thickness of Wall as Shown in Figure 1. The Pipe, When Welded Joints are Used, is not Weakened by Cutting the Threads and Thereby Decreasing the Thickness of the Wall.

Advantages of Welded Joints

When using a welded joint it is, therefore, possible to use a pipe having a thickness of wall nearly one-half the thickness required when threaded pipe joints are used. This means a tremendous saving in the steel required for pipe lines and a very considerable saving in weight when the pipe is used in building construction. There is also a very advantageous saving if the pipe is used aboardship where additional weight counts for so much. Furthermore, the welded joint provides smooth internal surfaces and makes it possible to use long radius bends or turns. This is so advantageous that in a heating installation using hot water for instance, it has been found that a welded installation having long bends will heat the water in the system in about one-half the time required when screwed fittings and sharp turns are used. This is because there is less resistance to the flow of water through the pipe and, therefore, the natural movement of the water caused by heat is more rapid than it would be otherwise.

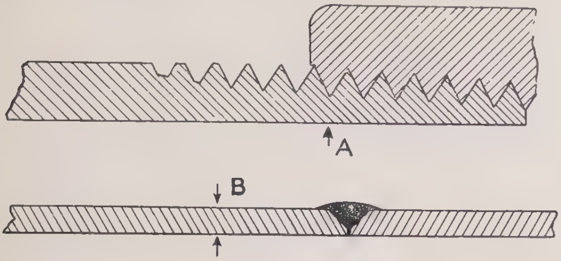


Figure 3—In A of This Figure a Part of the Coupling and the End of the Pipe are Shown in a Threaded Pipe Joint. In Many Instances the Coupling Does Not Screw Up On the Thread of the Pipe as Far as It Should and the Strength of the Joint is Dependent Upon the Thickness Between the Bottom of the Thread and the Inside Wall of the Pipe as at A. This is Often No More Than About One-half of the Strength of the Wall of the Pipe at Its Full Section. At B is Shown a Butt Welded Pipe Joint With a Thickness of Wall B, Equal to the Thickness A, Which Will Develop the Same Strength as the Threaded Joint Shown Above It.

Most important of all is the fact that the welded joint will not leak after it has once been made. It is in reality a union of the steel making all of the pipe practically one piece and if the pipe is once tested and proved tight, it is improbable that leaks should develop. There is, therefore, no upkeep required in a welded line, such as is usually the case in a threaded line. Leaks in threaded joints are the torment of the maintenance man in a manufacturing plant or a railroad shop. This is particularly true where the threaded lines are carried by the crane girders or are suspended from them and the vibration of the crane, as it travels up and down the runway, continuously jars the joints until finally they become leaky.

There is another factor which will be given consideration later and that is the cost of making a welded joint compared with that of a screwed joint. In the small diameter pipe, it is likely that the average welded joint will cost as much as the screwed coupling, but this can only apply to the very small pipes and the saving in the cost of steel must not be forgotten. In the larger sizes the saving is very great. This, however, will be considered separately in Lesson No. 6. Generally speaking, therefore, the advantages of welded joints over the screwed fittings, naming them in the order of their importance, are as follows: They will not leak, have greater strength, save nearly half the weight of the steel in the pipe line, present much less internal resistance to the flow of liquid passing through them and cost less money to construct.

Preparation of Edges of Pipe for Welding

The maximum diameter of pipe considered in this lesson is two inches. Pipe of this diameter is considered to be small pipe and pipe greater in diameter than two inches has been placed in the large pipe field. The thickness of the wall of two-inch pipe is very close to five-thirty-seconds of an inch. It is for this reason unnecessary to bevel the edges, but care must be taken in welding two-inch pipe to be sure that the weld penetrates clear through the section of the metal. Most of the pipe in the small pipe field is cut with the oxy-acetylene torch. There is a circular saw bit which can be attached to an electric drill which has been found very convenient for cutting holes in small pipe. This bit is like an inverted bowl made of steel with teeth cut in the edges of the bowl and the bottom of the bowl attached to a shank connected to the electric drill. The steel shank extends through the center of the bowl and forms a center drill in the plane of the teeth. A center punch mark is made in the pipe where the hole is to be cut and it is quickly sawed through the wall. This arrangement is excellent where accurately cut holes are required.

For most purposes, however, the cutting torch is used quickly and conveniently and the holes have sufficient regularity for ordinary joints. It is important, however, that the oxide or slag which clings to the edges of the pipe after it has been cut with a torch be removed before welding is attempted.

The only preparation necessary, therefore, for pipe two inches and less in diameter is the cutting of the pipe as nearly as possible in the plane to be welded and the subsequent cleaning off the oxide, being sure that the edges are clean, solid metal. Cutting the pipe in the plane to be welded is indicated in Figure 4. If a pipe were to be cut so that the two pieces could be placed together to form an elbow, it would be necessary first to mark the line of cut around the circumference of the pipe in the angular plane in which the pipe is to be cut. In cutting, it is essential to hold the torch in such manner that the flame and the jet

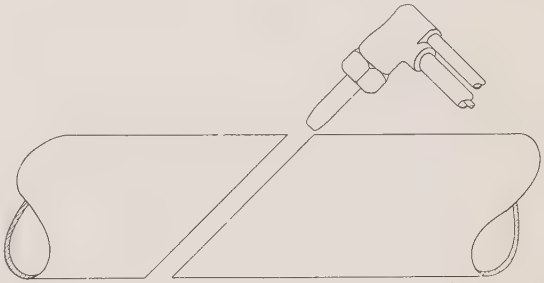


Figure 4—Sketch Showing the Plane in Which the Cut Should be Made in Cutting a Pipe for a Ninety Degree Ell. The Torch Should Not be Held Perpendicular to the Surface of the Pipe, But Should be Moved Around the Outside of the Pipe in the Plane of the Cut, Which in This Instance Would be Forty-five Degrees With the Center Line of the Pipe. This is the Same Kind of a Cut That Would be Obtained if a Saw Were Placed at the Same Angle and the Pipe Sawed Through. When the Two Pieces are Turned About They Will Form a Ninety Degree Elbow.

of oxygen will project the cut in this plane. This is shown in Figure 4 which illustrates the angle for cutting a pipe at forty-five degrees for the welding of a ninety degree elbow.

Cutting Pipe

If the cutting of pipe is to be accurately done, the line of the cut to be made with the torch must be accurately marked on the pipe. This may be simple enough in some instances but in others, involving more or less complicated joints, it becomes a matter requiring considerable knowledge of templet making. The making of templets for marking out pipe to be cut is not difficult, but it is necessary that a drafting board, a tee square and a few of the more common drafting instruments, together with some drawing paper, be available.

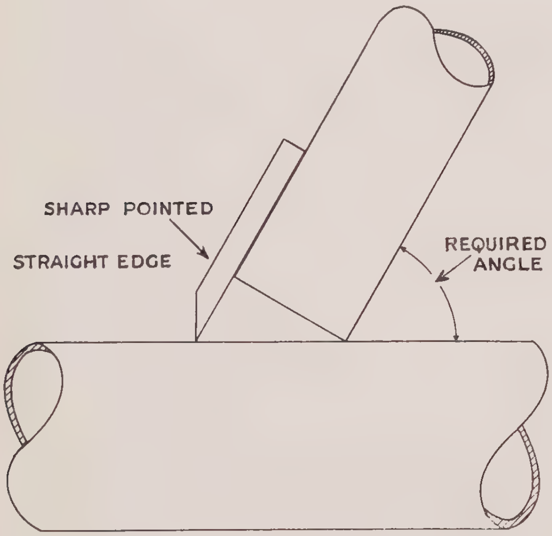


Figure 5—This is an Illustration of a Rough Method for Marking a Hole in the Pipe When a Smaller Branch is to be Made in a Larger Pipe. When the Branch is the Same Diameter as the Larger Pipe, the Method Does Not Work Very Well. It Consists of a Pointed Straight Edge Slid Around the Pipe, Marking the Extension of the Circumference of the Smaller Pipe on the Larger. The Method May be Used for Any Degree of Angle, or for a Right Angle Branch if Desired.

With this lesson are supplied templets for cutting one inch, one and one-quarter inch, one and one-half inch and two-inch pipe, also for cutting one inch branches from two-inch pipe, for the closing of the end of two-inch pipe and the making of a reducer from two-inch pipe to one-inch pipe. There are twelve of these templet sheets printed on pages Nos. 69 to 80 inclusive. They should be used as follows:

Thin brass sheets should be procured, or if brass is not available, tin or galvanized iron. A tracing of the templet sheet in the book should be fastened to a brass sheet with shellac. After it has dried the line indicated upon the tracing should be cut with a punch through the paper and the brass. This will produce a series of small holes along the line through which chalk marks can be made on the pipe. The templet sheets are similar with the exception of templet sheets Nos. 10, 11 and 12. The description of Sheet No. 1 will, therefore, apply to Nos. 2, 3, 4, 5, 6, 7, 8 and 9.

The narrow dimension, 4.131 inches, of templet sheet No. 1, is the circumference of a one-inch pipe. It should be remembered that one-inch pipe is not exactly one inch in diameter. The one-inch nominal size is approximately 1.049 inches in internal diameter and 1.315 inches in external diameter. The narrow width of the templet sheet is, therefore, just wide enough to wrap around the outside of a one-inch pipe. The thin brass templet sheet can be similarly wrapped around the pipe and, with a piece of chalk, marks are made upon the pipe through the holes which have been cut in the templet sheet in the same manner that a stencil is used. The little sketches shown near each templet indicate the joints for which each templet is to be used. For instance, if a ninety degree elbow is to be made with two forty-five degree welds, the end of each piece of pipe should be cut along a line drawn through the chalk marks made through the holes punched along the line of the templet marked with the arrow.

For a sixty degree single weld bend, there is also one templet to cut the end of each pipe. In like manner, one templet will cut the end of each pipe for the ninety-degree elbow, indicated by the sketch. For the right angle branch of one-inch pipe into one-inch pipe, there are, however, two templets. One of these, indicated by an arrow, is used to cut the hole in the side of the main pipe and the other also indicated by an arrow, to cut the end of the pipe for the branch.

In similar manner, the forty-five degree branch and the ninety degree Y, shown upon templet sheet No. 2 are used. The other templet sheets are drawn for each size of pipe, so that similar joints in other diameters of pipe can be made.

Templet sheets Nos. 10 and 11 differ from the other sheets because they are arranged for branch one-inch pipes into two-inch pipes. These branches are thirty degrees, forty-five degrees, sixty degrees, and ninety degrees as shown. Templet sheet No. 9 shows templets for cutting a 45 degree branch in two-inch pipe. Templet sheet No. 12 indicates lines for cutting a pipe end two inches in diameter so that the ends can be bent in and welded to close the end of the pipe. The lower templet of templet sheet No. 12 indicates the manner in which two-inch pipe must be cut and bent to make a reducer from a two-inch to a one-inch pipe.

These templets will be found very valuable in cutting pipe. It is much easier to use a templet which will accurately show the lines to be cut than it is to attempt to draw the line in a rough manner with a sharp pointed straight edge, as shown in Figure 5. This is a very practical method for marking the hole in a pipe when making a branch, if the branch pipe is smaller than the main pipe, but at best, it is a makeshift that should be used only if templets are not available. When the hole has been cut along the line made by drawing the pointed straight edge around the pipe, the branch pipe may be slipped through the hole and a mark made around it with a piece of chalk. The branch pipe may then be cut off with a cutting torch and the two parts set together and tacked. When the angle has been checked and if necessary the branch bent slightly one way or the other, the weld can be completed.

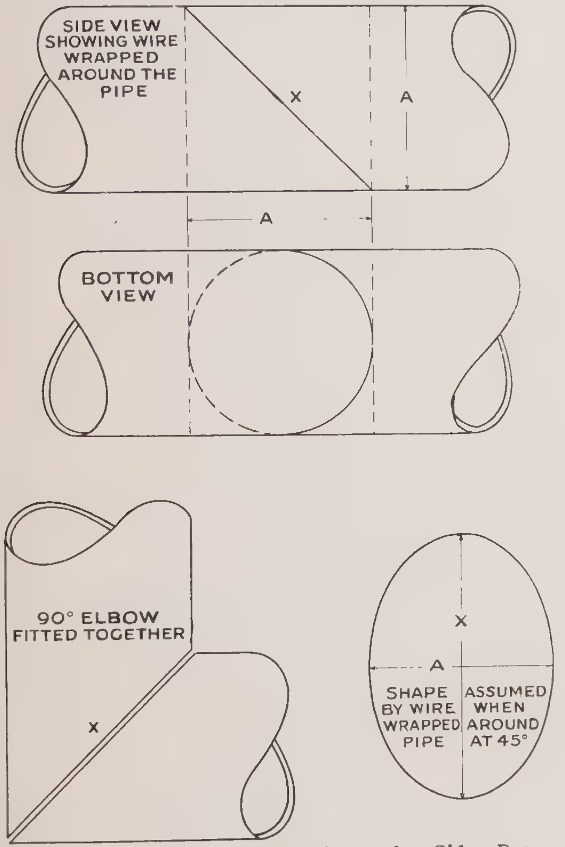

SIDE VIEW SHOWING WIRE WRAPPED AROUND THE PIPE
X
A
A
BOTTOM VIEW
90° ELBOW FITTED TOGETHER
X
X
A
SHAPE BY WIRE WRAPPED PIPE
ASSUMED WHEN AROUND AT 45°

Figure 6—These Sketches Indicate the Side, Bottom and Assembled Views of Pipe to be Cut to Make a Ninety Degree Elbow as Shown. This is a Rough and Ready Method, Using an Elliptically Bent Piece of Welding Wire as a Marker. This Method is Fully Described in the Text.

A ninety degree elbow can be cut by a rough and ready method, shown in Figure 6. An ordinary leather belt is wrapped around the pipe and a piece of soapstone used to mark around the belt. The outside diameter of the pipe is then determined and a distance A laid off along the side of the pipe, equal to the outside diameter. A line is drawn around the pipe at this mark using the belt as in the first instance. A piece of light welding wire is then bent around the pipe as indicated by the line X in the upper view and the circular line in the middle illustration of Figure 6. This piece of welding wire may be welded together at the ends and takes the form of an ellipse shown at the lower right. This ellipse appears to be a circle when looking directly at the bottom of the pipe as in the bottom view. In the lower left illustration in Figure 6, the pieces of pipe cut as described are shown fitted together to make a ninety degree ell.

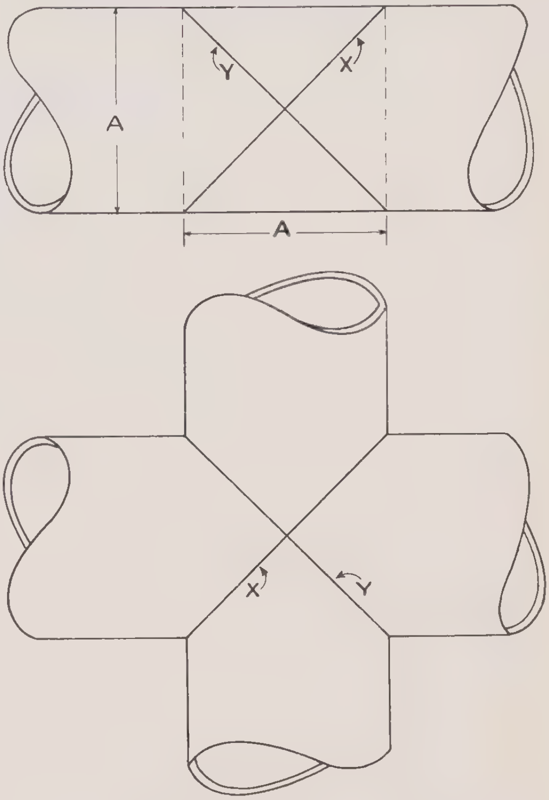


Figure 7—These Sketches Illustrate a Similar Method for Cutting Pipe to Make a Cross. It is, of course, Assumed That Both Lengths of Pipe are of Equal Diameter.

A forty-five degree ell may be made in exactly the same way by making the distance A equal to one-half the diameter of the pipe.

The elliptical line X, may be quickly and easily determined at any point along the pipe if the welding wire used is made a permanent templet by carefully shaping it until it just conforms to the surface of the pipe at a forty-five degree angle and welding the ends. It may then be slipped over the end of the pipe and used as many times as desired.

Another way of determining the line of cut for a ninety degree ell is to hold one end of the pipe in a pail of water so that the center line is at an angle of approximately forty-five degrees with the surface of the water. The surface of the water will then make an elliptical line around the surface of the pipe which will be the ellipse described above and will indicate the line of cut.

In Figure 7 the same principle is applied in the cutting of pipe to make a cross. In this instance both lines X and Y are marked as illustrated in Figure 6. The cut is made along the lines X and Y in two lengths of pipe, and the four pieces of pipe placed together in the shape of a right angle cross. Figure 8 shows how a tee can be made in a generally similar manner by drawing the lines X and Y as shown in Figure 7. Instead, however, of cutting the entire circumference of the pipe, the section C only is cut out and discarded. A piece of pipe for the branch is then selected and a distance equal to one-half of the diameter A is laid off from the end of the pipe. Lines are then drawn to the center of the end of the pipe as shown and cut. The branch pipe thus cut will fit into the opening left after the piece C has been removed. This will make a tee, as shown in the lower sketch of Figure 8.

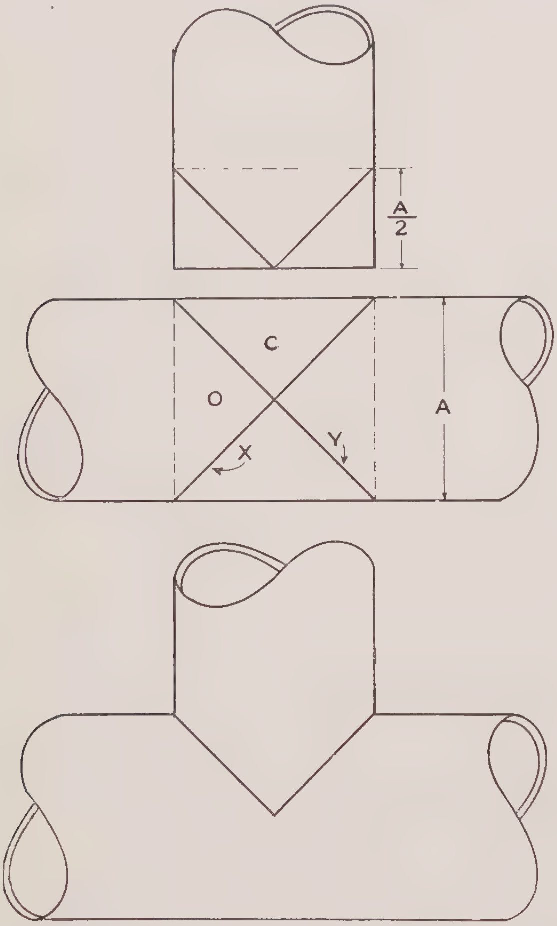


Figure 8—In Like Manner Pipe May be Cut to Make a Ninety Degree Branch From Pipe of Equal Diameter.

There are many other rough and ready rules for cutting pipe, but the most satisfactory way in which to make these fittings is to use the templets furnished with this lesson. They will provide accurate lines and if the cutting is carefully done, the sections will fit together to make the welding of the pieces easier and to assure accurate angles.

These templets, as stated above, are not difficult to make and the same general principles apply to all of them. In order that the student may know just how templets are laid out, an explanation has been given of the construction of a templet for making a ninety degree elbow, shown in Figure 9, and a templet for making a Y branch, shown in Figure 10. These are both fully described in the following paragraphs.

Laying Out a Templet for Cutting a 90 Degree Elbow

In Fig. 9 the construction is shown of one of the simplest forms of templets. It is the templet used for cutting the ends of two pieces of pipe of the same size to form a single weld ninety degree elbow. To develop this templet first a full size outline of the fitting is made as at A. Then, as shown, a semi-circle is drawn having a diameter equal to the diameter of the pipe and the circumference of the semi-circle divided into any number of equal parts. Fig. 9 shows the semi-circle divided into twelve parts. From each of these eleven points lines parallel to the sides of the pipe have been projected until they meet the line representing the joint between the two pieces of pipe. These lines are called ordinates. Each of these ordinates should be numbered as indicated.

It will be noted that all of the ordinates, with the exception of the edges of the pipe, have two numbers. If instead of drawing only a semi-circle, a complete circle was drawn, points 12 and 14, 11 and 15, 10 and 16, etc., would be exactly opposite each other on the circle and a line drawn through point 12, parallel to the sides of the pipe would pass through point 14. Therefore, in order to simplify the drawing, it is customary practice to draw only a semi-circle and to give each point except the edges, two numbers. When numbering these ordinates, an edge of the pipe should be called number 1 and the numbering continued consecutively until the opposite side is reached, then back again until the first side is again reached. Next, a line should be drawn, such as C-C, at right angles to the pipe, as illustrated. This line may be at any convenient distance D from the joint and merely serves as a reference line when measuring the length of the ordinates.

After all of the above steps have been completed, a line should be drawn exactly as long as the circumference of the pipe, shown as C-C, at B, Fig. 9. This line is called the base line, and is carefully divided into twice the number of equal parts as the semi-circle in A and lines perpendicular to C-C are erected at each of these points. The line at each end is numbered 1, and, starting at the left, the next line is numbered 2, the next 3, etc., until all of the lines are numbered.

Now, a pair of dividers, a rule or other measuring device, is used to lay off on line number 1, in B, the exact distance on line 1, in A, from line C-C to the joint between the two pieces of pipe. Next, the distance along line 2, 24 in A, from line C-C to the joint, is laid off on lines 2 and 24, in B. This method is continued until all of the intersections of the ordinates and joints in A have been marked on the corresponding lines at B. The next and final step is to connect these points with a smoothly curving line, such as illustrated at B.

Because both pieces of pipe, in this case, are cut at an angle of 45 degrees, it is necessary to make only one templet.

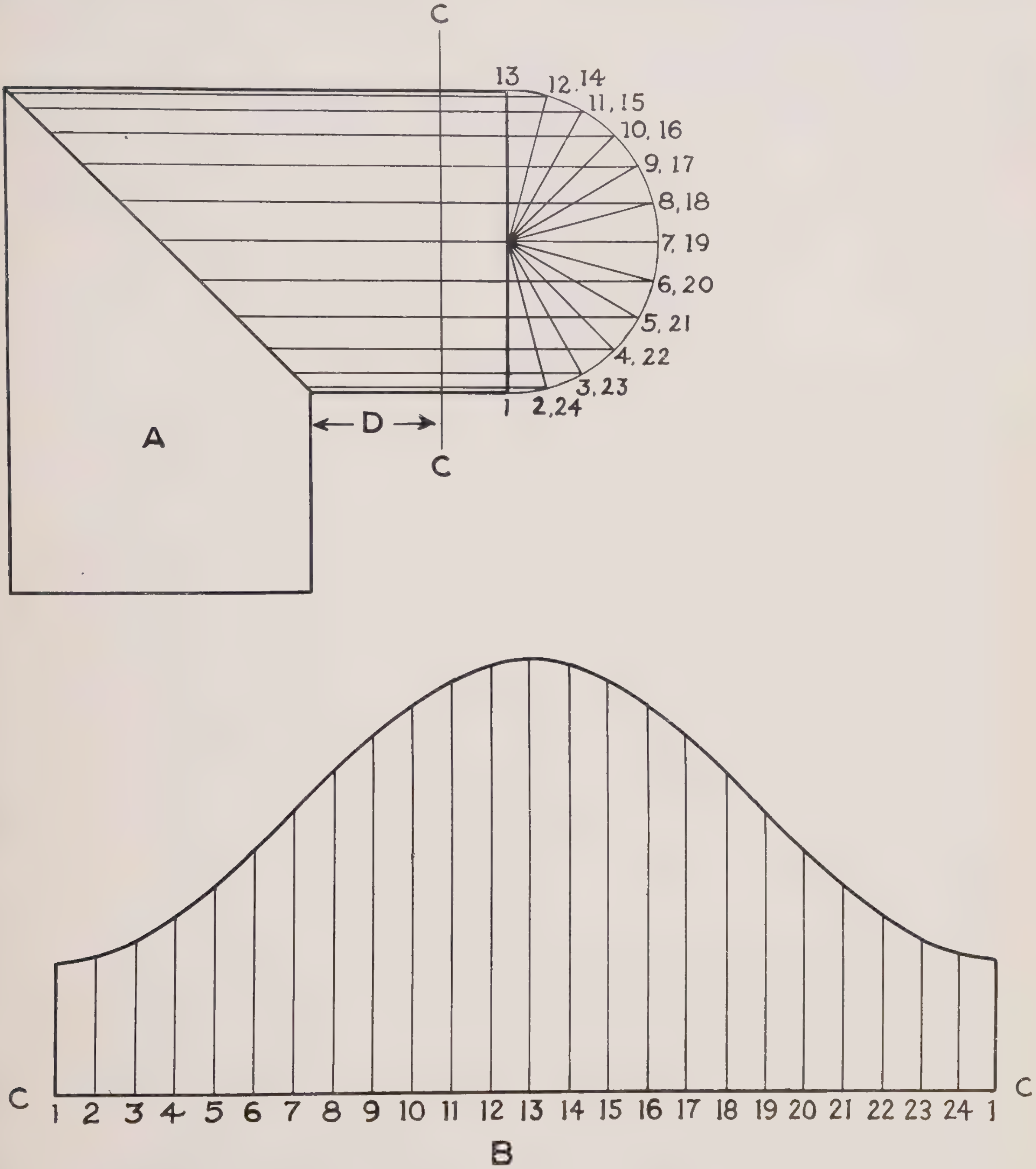


Figure 9—This Drawing Shows the Development of a Templet for Cutting the Ends of Pipe to Make a Single Welded 90 Degree Elbow. The Completed Templet is Shown at B.

Making a Templet to Cut a 90 Degree Y Branch

Figure 10 shows the intersection of three pieces of pipe to form a Y. This joint requires two templets. One for the main line of pipe and one for the two branches. The branches require only one templet as they are cut exactly the same, the only difference being in their position.

The method of making the templets in this case is the same as that shown in Fig. 9.

First a sketch is made of the joint, then the semi-circles are drawn and divided and the ordinates and the reference lines A-A and C-C are drawn. Next the base lines B-B and D-D are drawn and divided into equal parts and a perpendicular line is erected at each point. The distances from the reference lines to the joints are then laid off on each of the ordinates and the curves are drawn in.

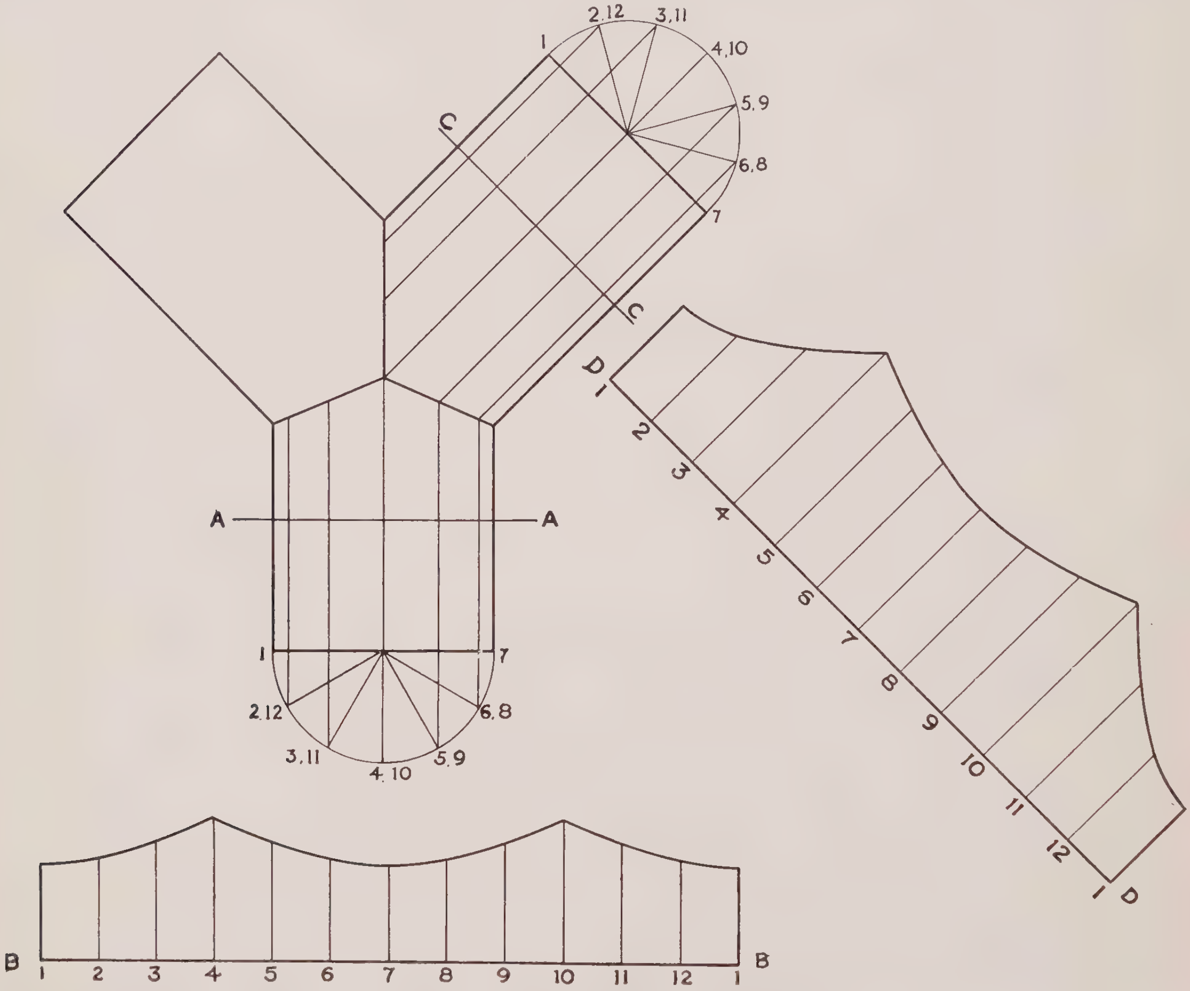


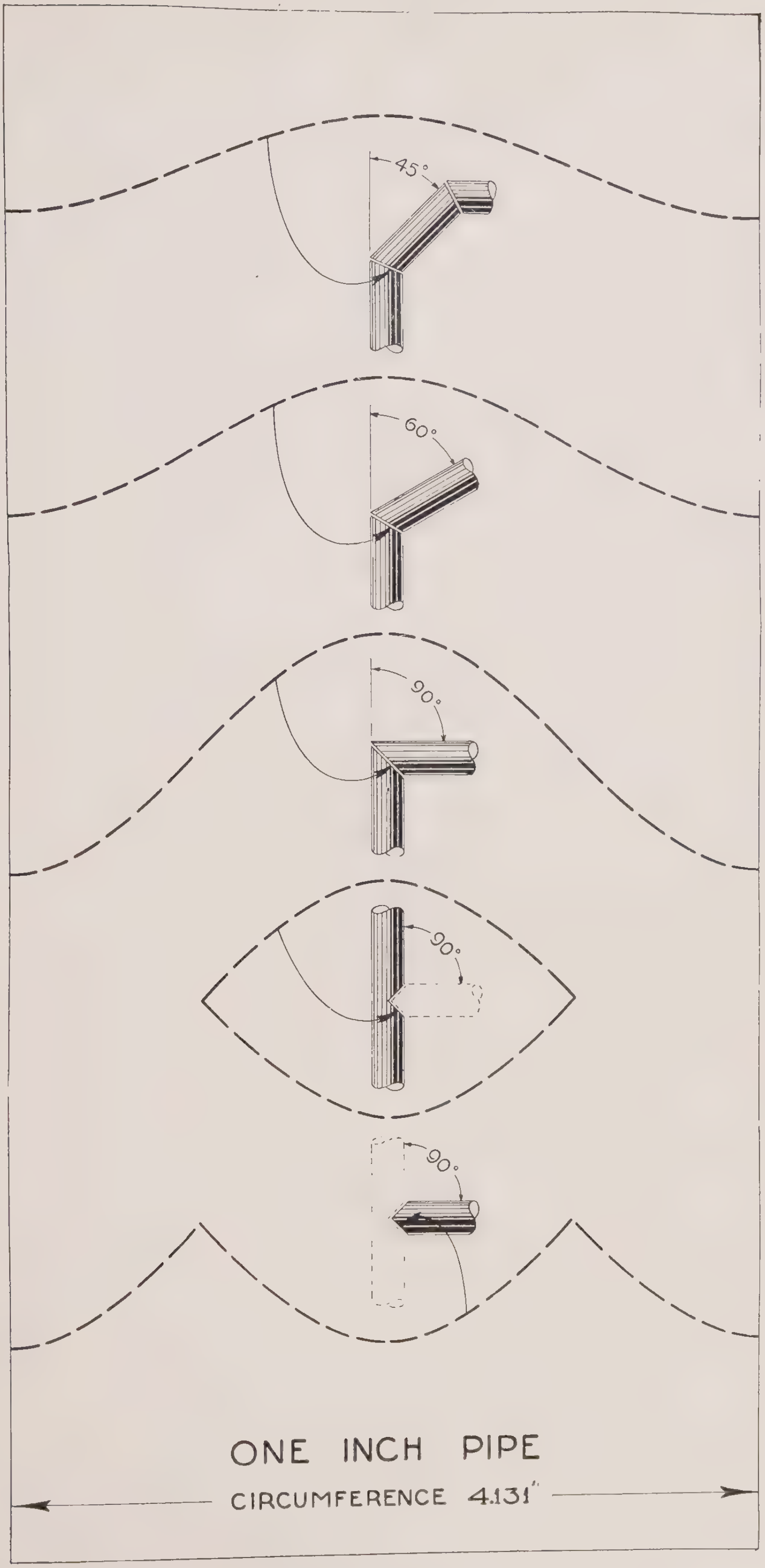
Figure 10—A Sketch Showing the Manner in Which Templets are Made for Cutting Pipe to Form a Y Branch.

It will be noted that Fig. 10 shows the semicircles divided into a fewer number of equal parts than Fig. 9. This was done to illustrate that the number of divisions is immaterial so long as sufficient points are obtained to permit the drawing of an accurate and smooth curve for the templet.

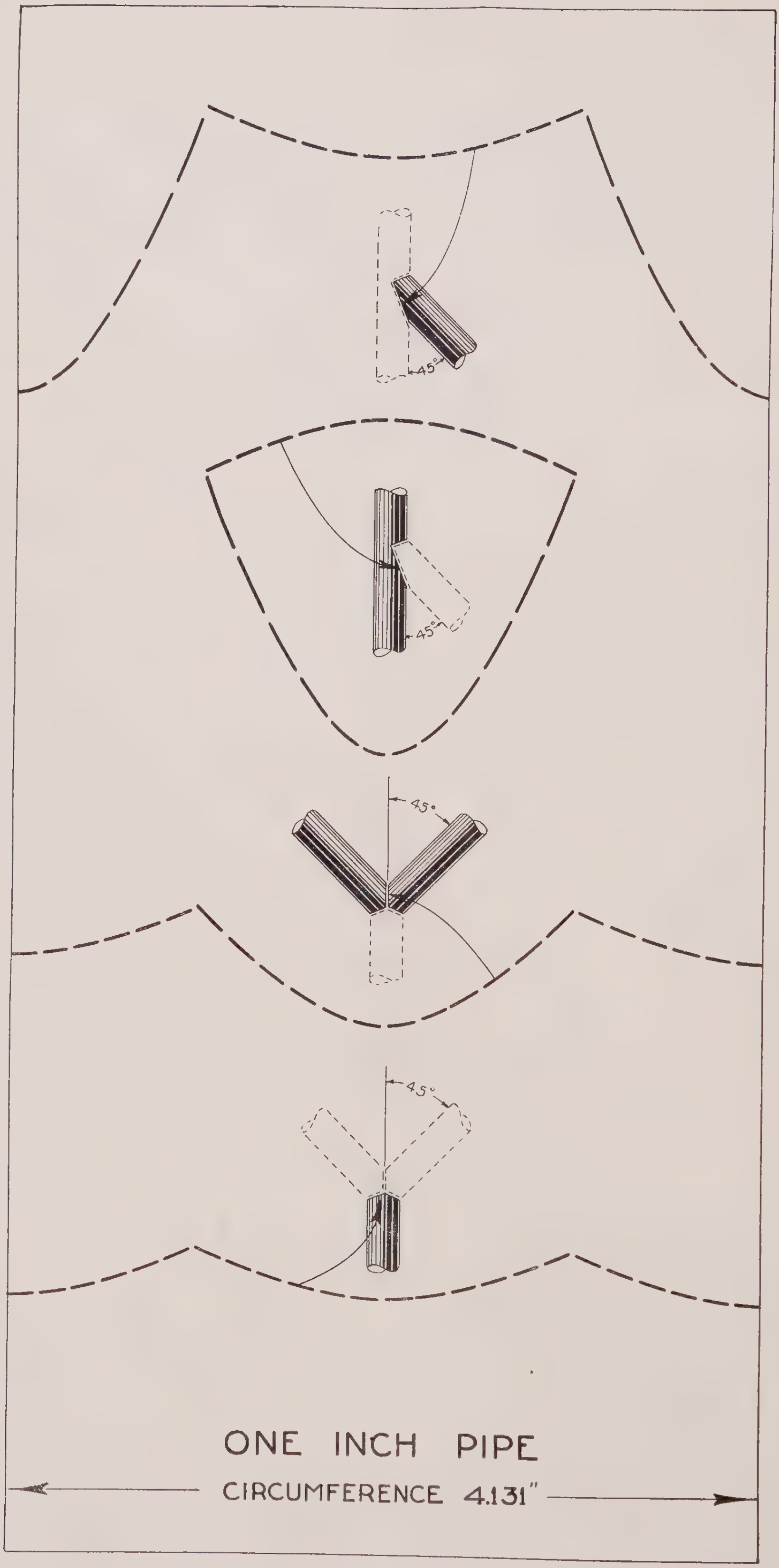
The Butt Weld Is the Best Weld

Accepted engineering practice for a number of years and more recently a very comprehensive series of tests, made by the American Gas Association, has proved that the butt joint, made by butting two lengths of pipe together and welding the circumferential seam, is the most satisfactory design of joint for pipe welding. As this lesson deals only with pipe not exceeding two inches in diameter, it is unnecessary to bevel the edges of the pipe as is usually the custom in making this type of joint. It will be explained, however, so that the welder will understand that when the pipe is larger than two inches in diameter and, therefore, the walls of the pipe are thicker, a forty-five degree bevel should be made on the end of each piece of pipe as indicated in Figure 11. It will be noted that the bevel does not extend clear through the pipe, but a straight section one-sixteenth inch in thickness is allowed to remain at the bottom of the bevel.

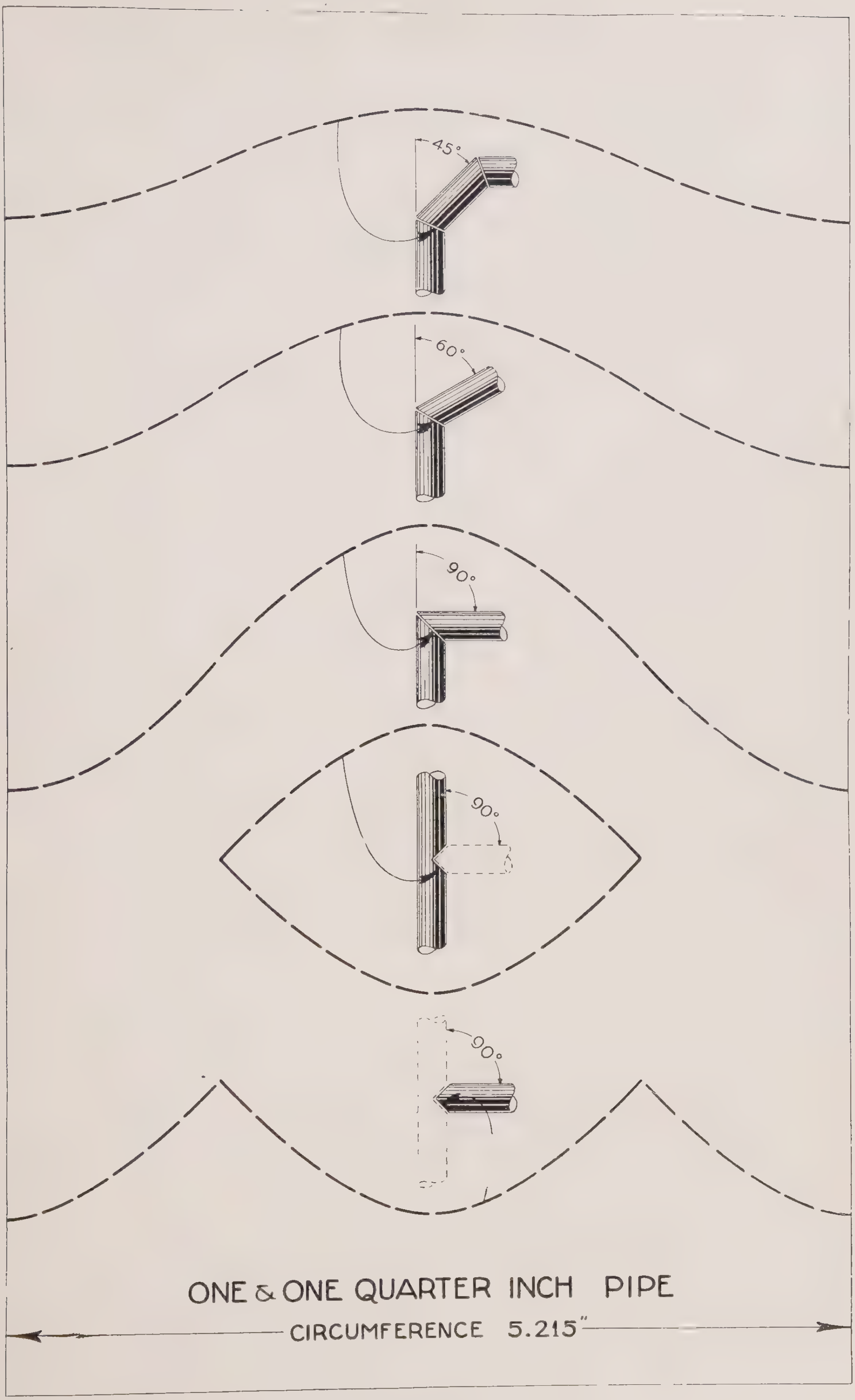
If the bevel is continued through to the inner surface of the pipe, a feather edge is the result and the welder is likely to burn or melt through this feather edge and form projecting drops of metal on the inside of the pipe which would make the joint rough. These projections would interfere with the flow of heavy liquids through the pipe. The bevel on the end of each piece of pipe is made at an angle of forty-five degrees with the surface of the pipe which gives an included angle of ninety degrees when the two pieces of


45°
60°
90°
90°
90°
ONE INCH PIPE
CIRCUMFERENCE 4.131"

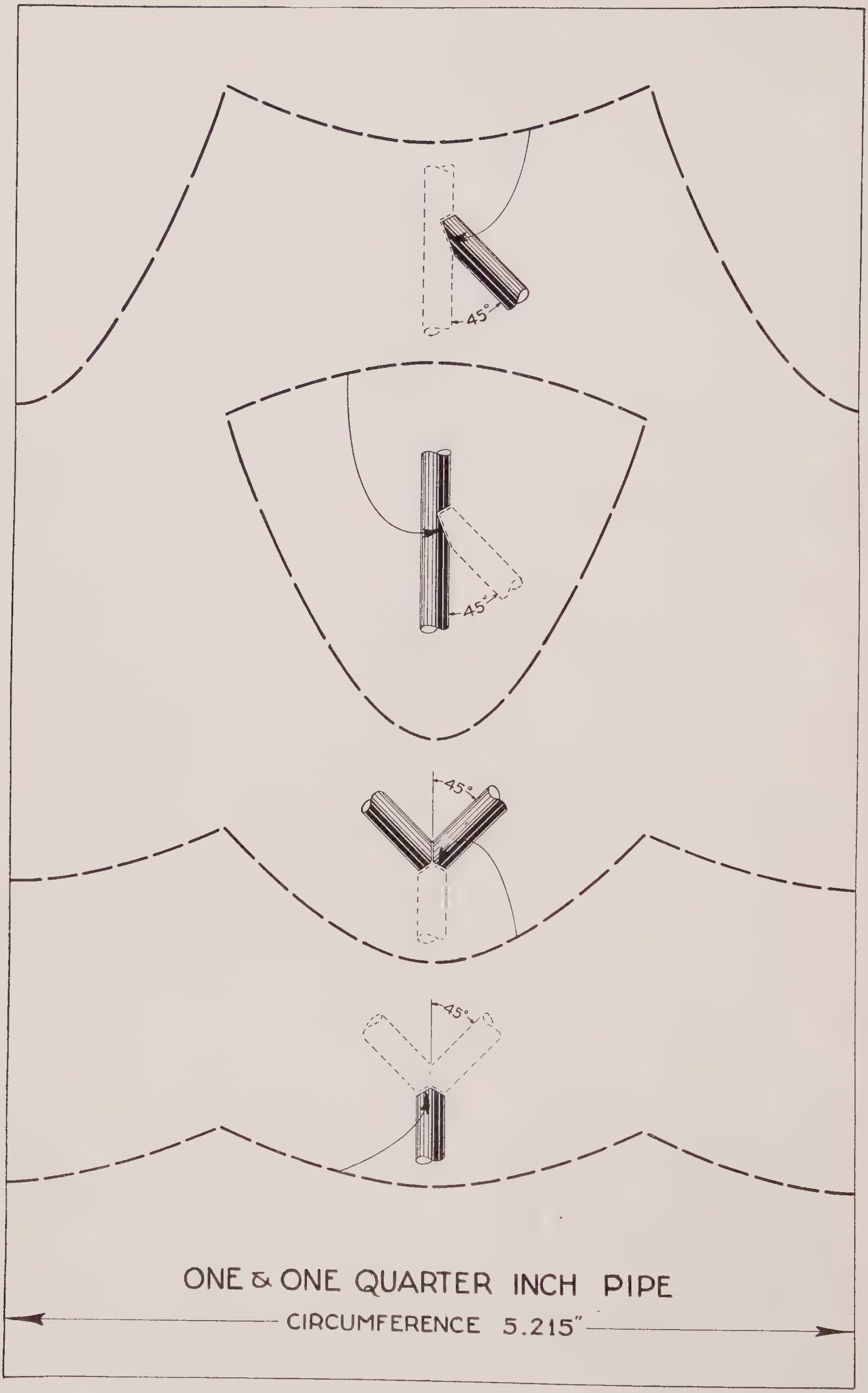
Templet Sheet No. 1


45°
45°
45°
45°
ONE INCH PIPE
CIRCUMFERENCE 4.131"

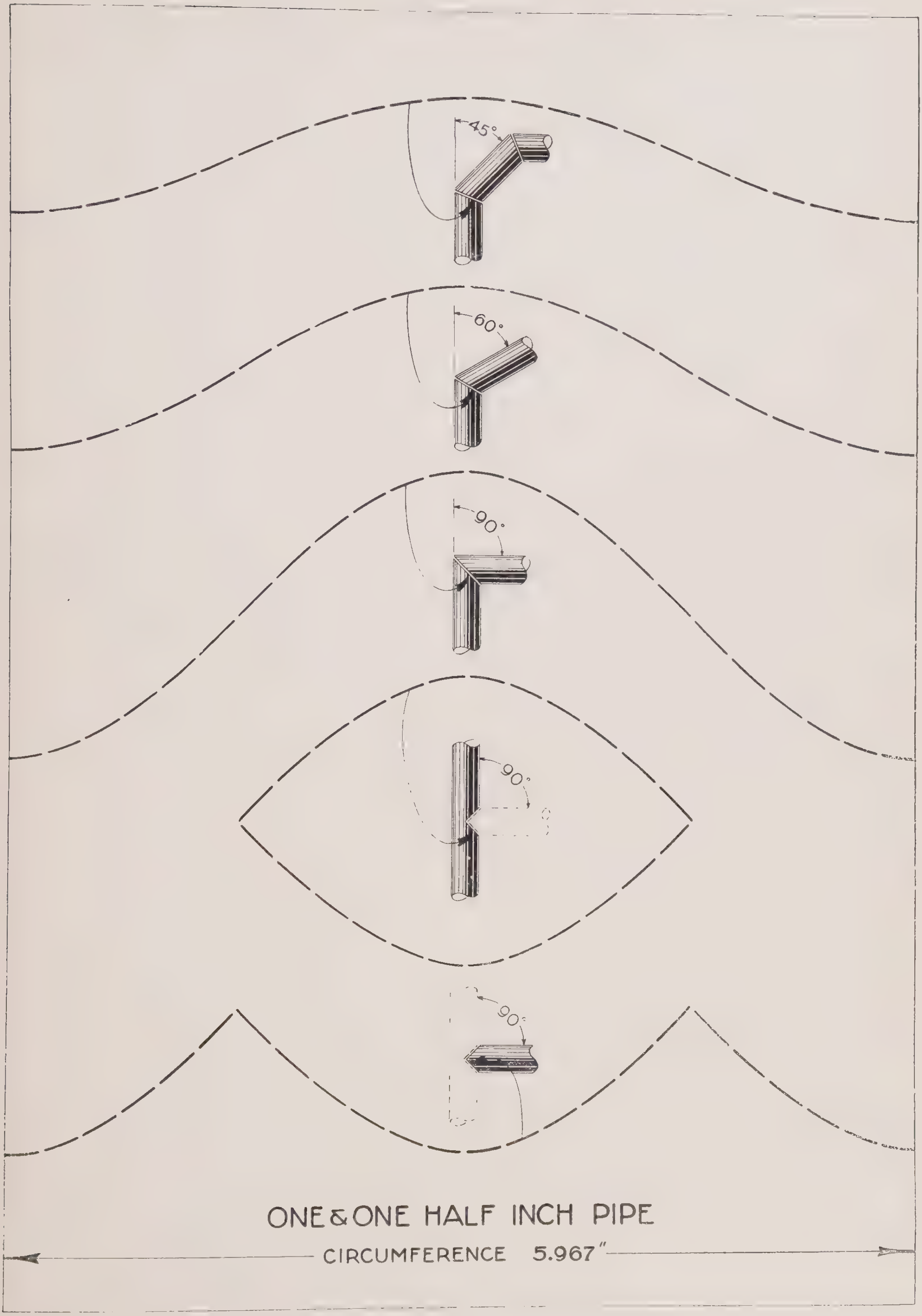
Templet Sheet No. 2


45°
60°
90°
90°
90°
ONE & ONE QUARTER INCH PIPE
CIRCUMFERENCE 5.215"

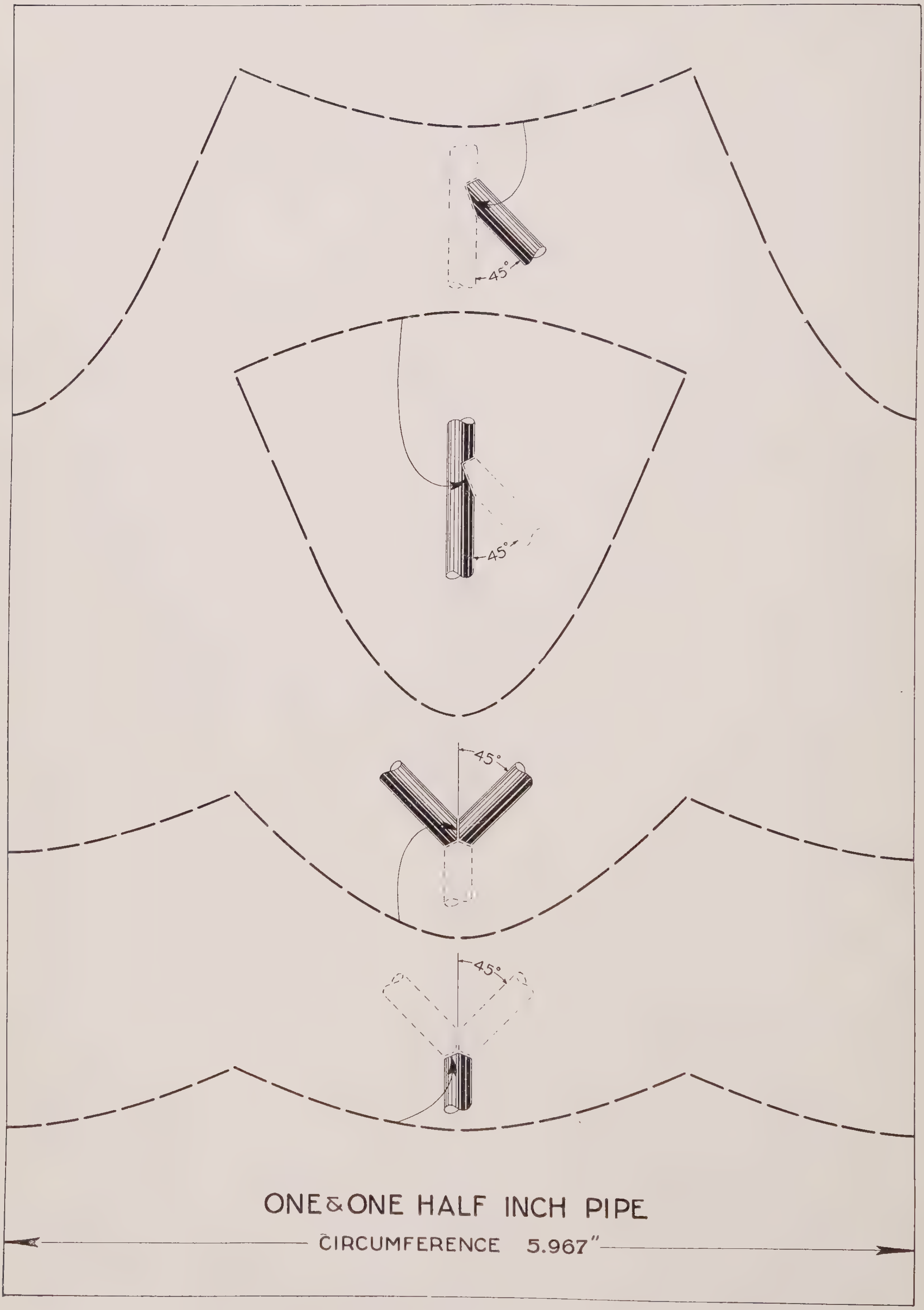
Templet Sheet No. 3


45°
45°
45°
45°
ONE & ONE QUARTER INCH PIPE
CIRCUMFERENCE 5.215"

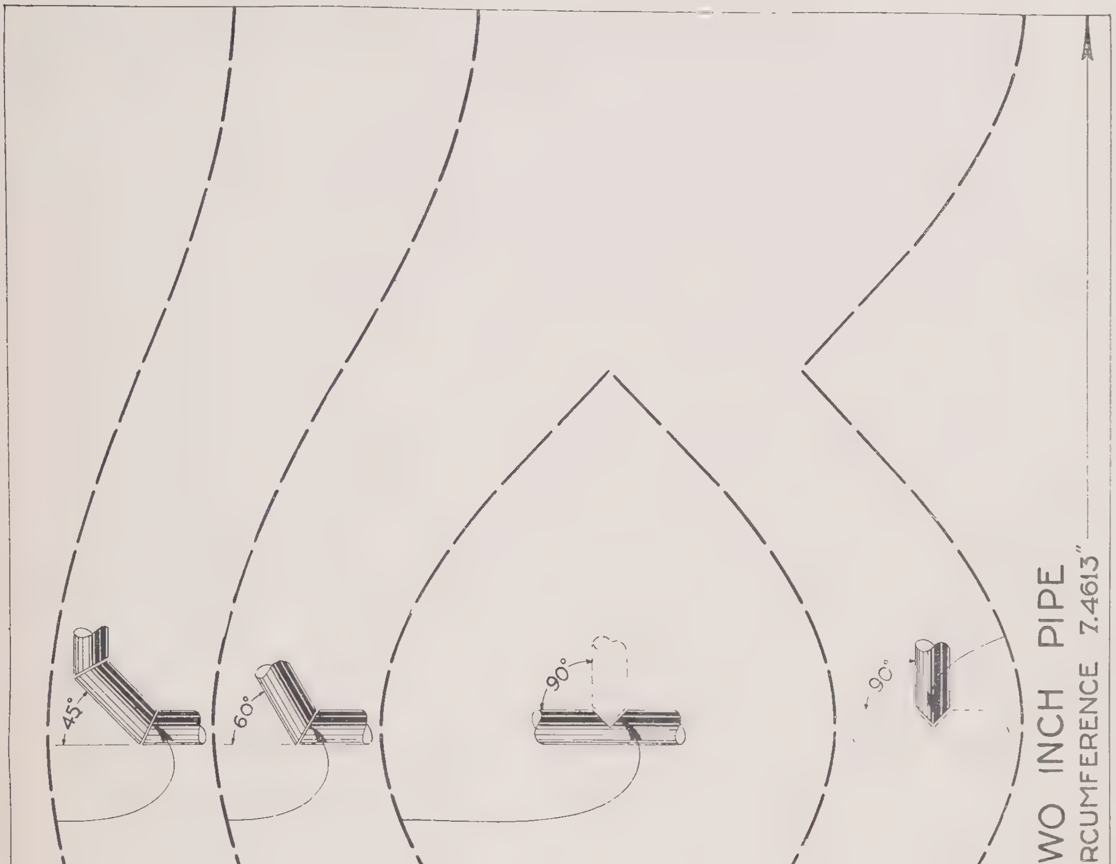
Templet Sheet No. 4


45°
60°
90°
90°
90°
ONE & ONE HALF INCH PIPE
CIRCUMFERENCE 5.967″

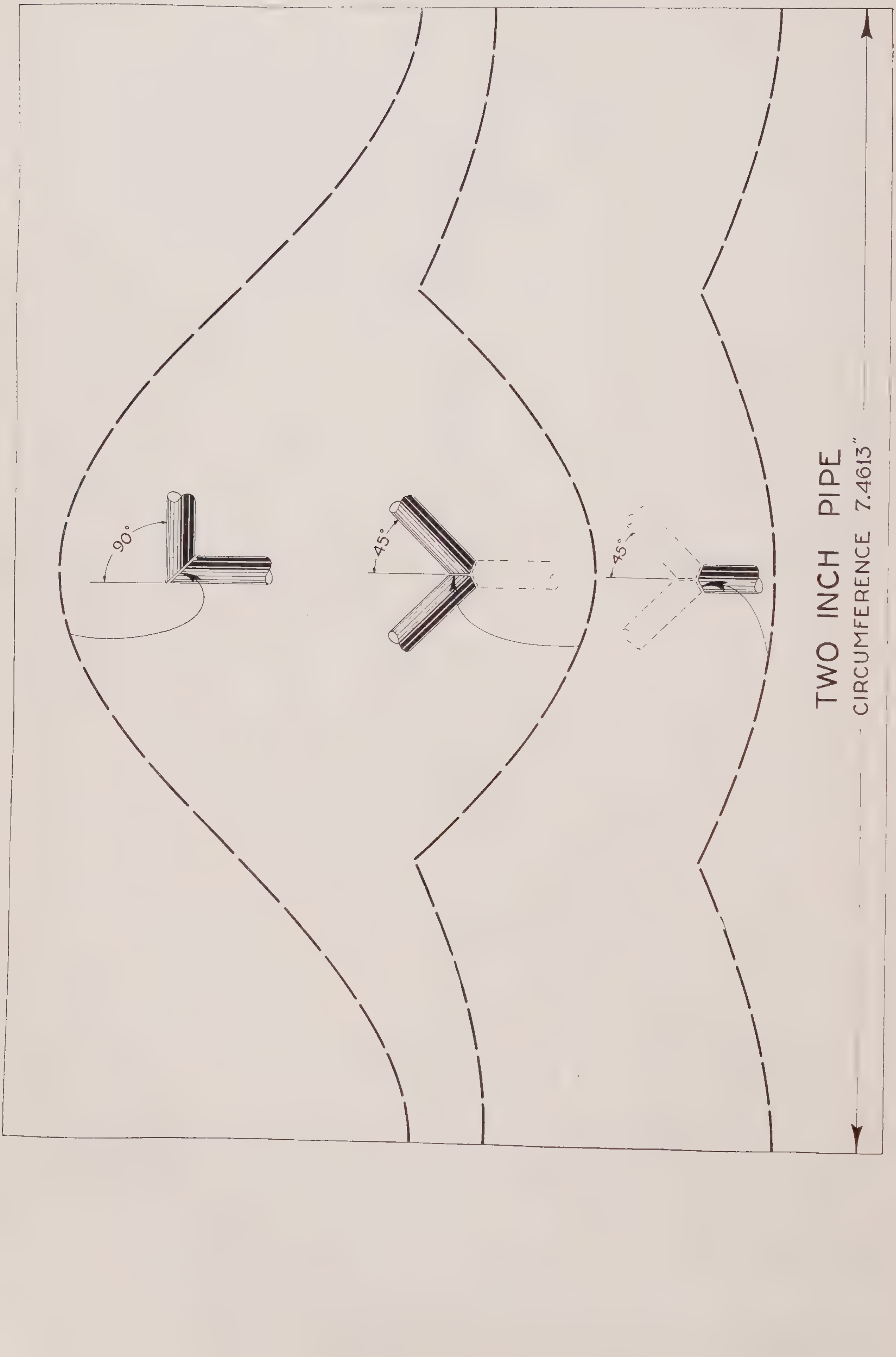
Templet Sheet No. 5


45°
45°
45°
45°
ONE & ONE HALF INCH PIPE
CIRCUMFERENCE 5.967″

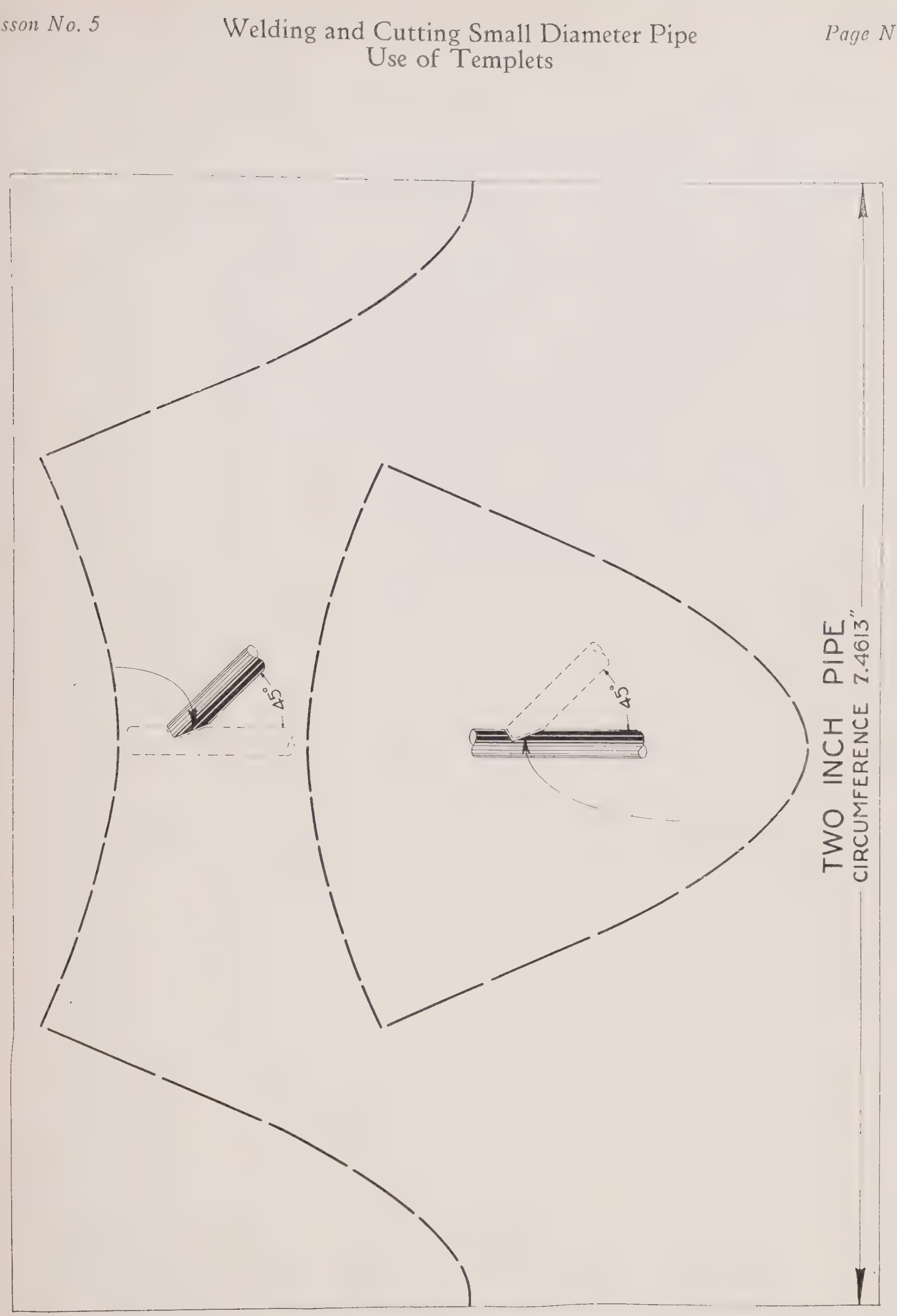
Templet Sheet No. 6


45°
60°
90°
90°
TWO INCH PIPE
CIRCUMFERENCE 7.4613"

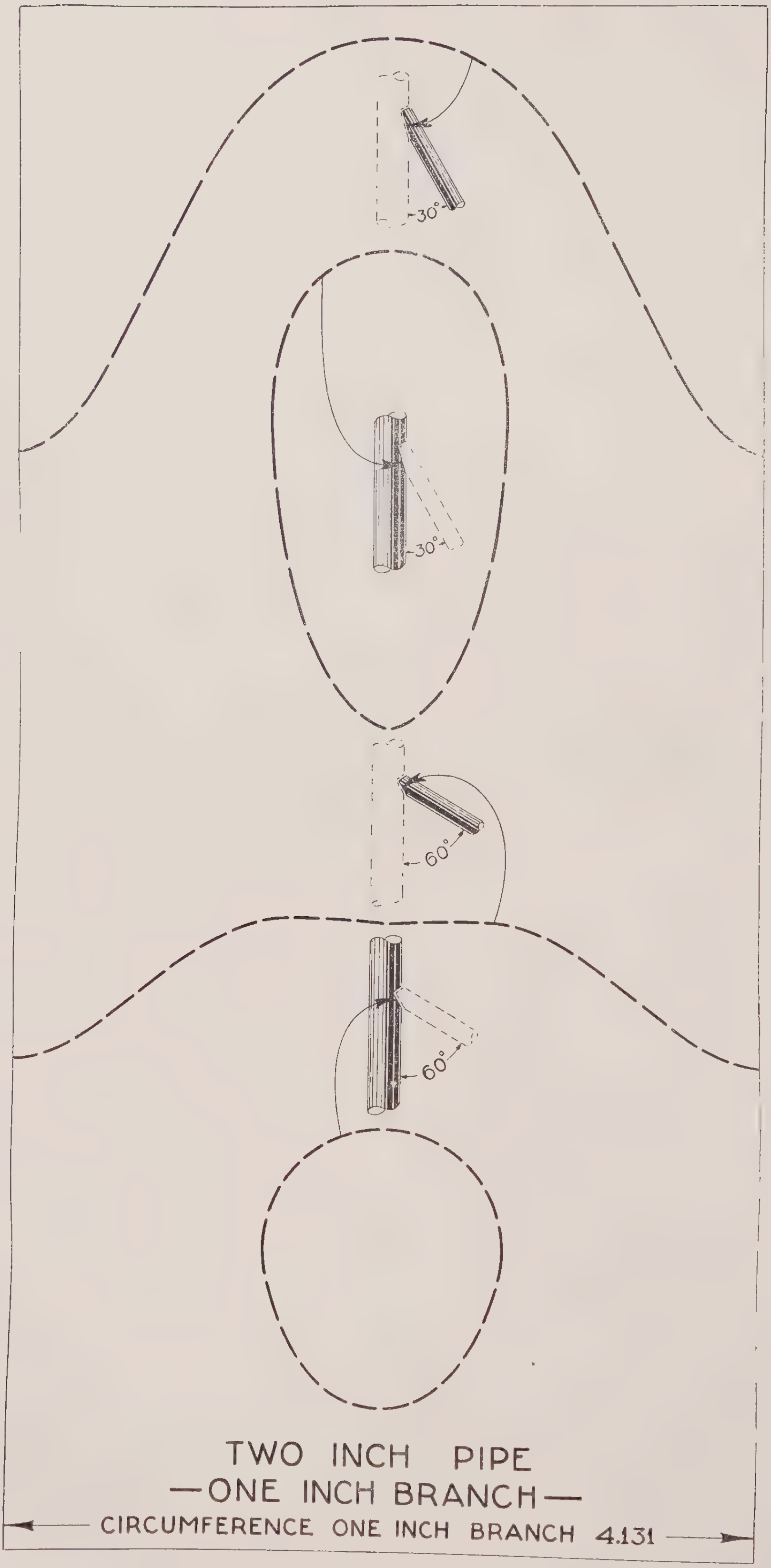
Templet Sheet No. 7


90°
45°
45°
TWO INCH PIPE
CIRCUMFERENCE 7.4613"

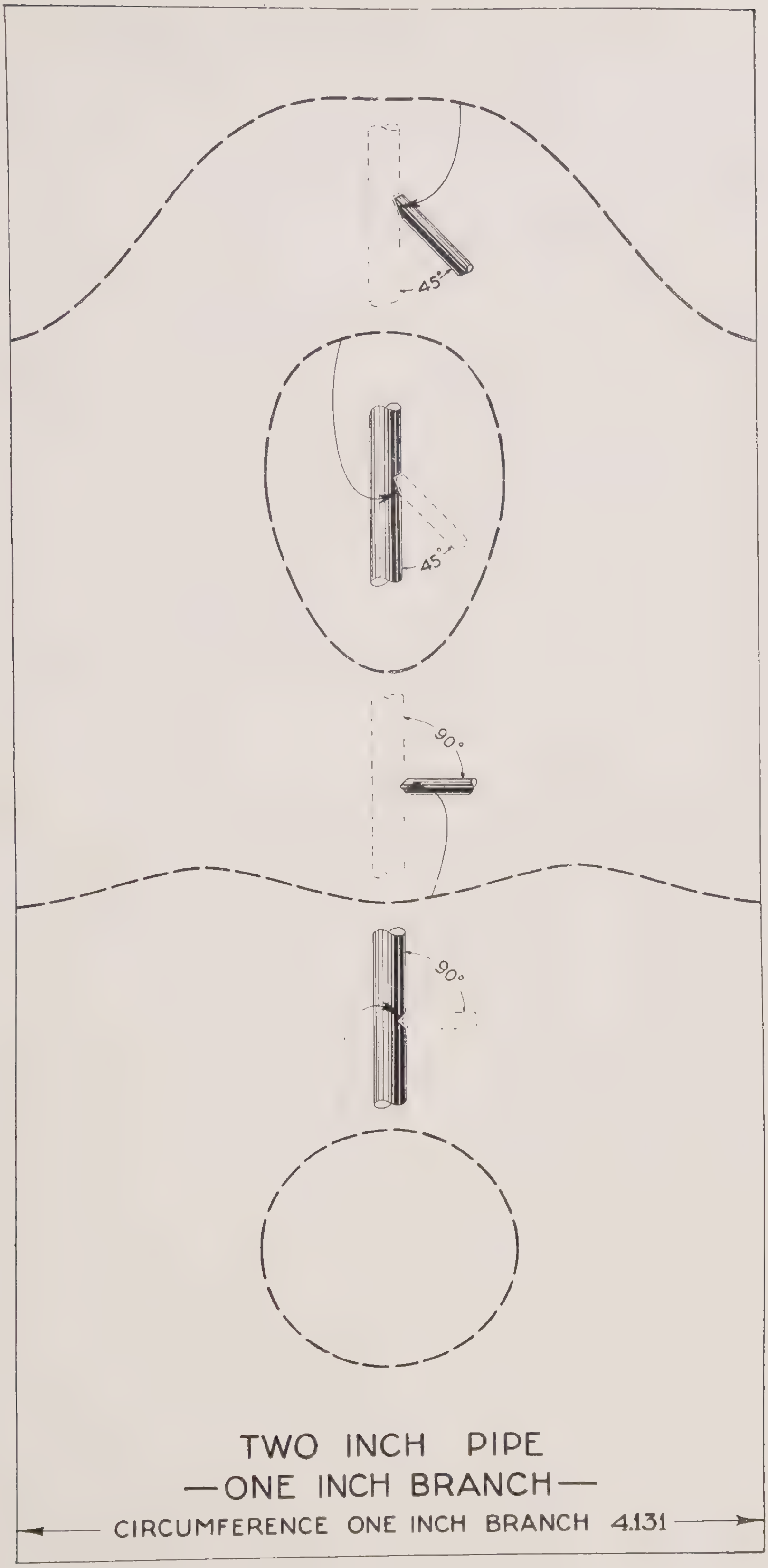
Templet Sheet No. 8


45°
45°
TWO INCH PIPE
CIRCUMFERENCE 7.4613"

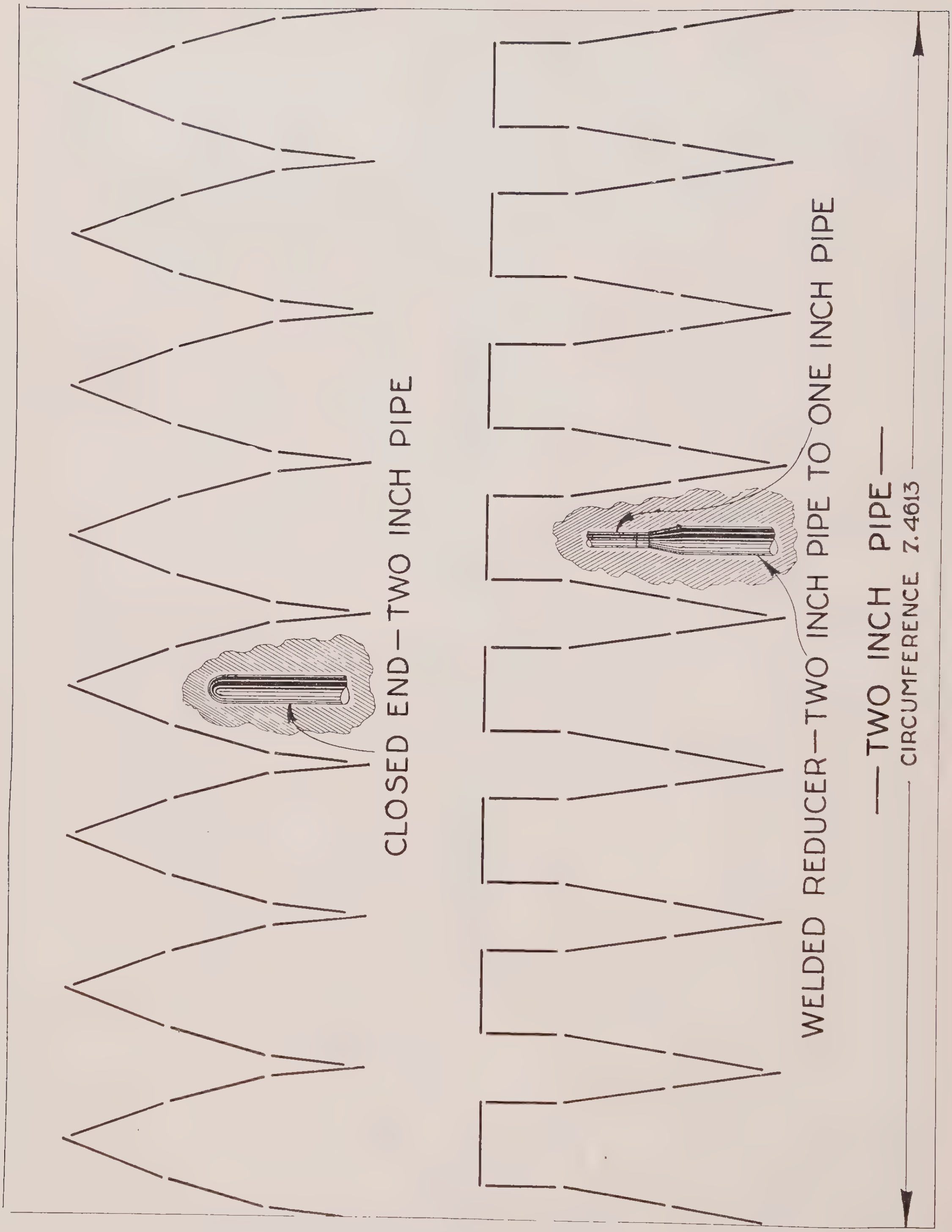
Templet Sheet No. 9


30°
30°
60°
60°
TWO INCH PIPE
—ONE INCH BRANCH—
CIRCUMFERENCE ONE INCH BRANCH 4.131

Templet Sheet No. 10


45°
45°
90°
90°
TWO INCH PIPE
—ONE INCH BRANCH—
CIRCUMFERENCE ONE INCH BRANCH 4.131

Templet Sheet No. 11


CLOSED END—TWO INCH PIPE
WELDED REDUCER—TWO INCH PIPE TO ONE INCH PIPE
—TWO INCH PIPE—
CIRCUMFERENCE 7.4613

Templet Sheet No. 12

pipe are placed together. If low carbon steel rod of the analysis given on page 14, Lesson No. 2, is used and the weld is built up twenty-five per cent thicker than the section of the wall of the pipe, the strength of the weld will be equal to the strength of the wall of the pipe. In fact, many tests of welds made in this manner show breakage of the pipe itself and not in the welded joint, indicating that the welded joint is even stronger than the pipe itself.

Tests made by the American Gas Association showed that butt welded joints in four, eight, twelve and sixteen inch pipe all had an average breaking strength of more than fifty thousand pounds per square inch. It may be safely assumed that joints made as indicated in Figure 11 will show a strength of at least fifty thousand pounds per square inch before the pipe will break. In these tests all of the four inch sections of pipe broke outside of the weld, indicating that the joint was in excess of one hundred per cent efficient.

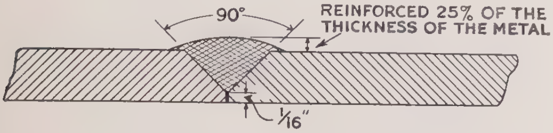


Figure 11—Sectional View of a Butt Weld Where the Pipe Wall is Thicker Than the Wall of a Two Inch Pipe and It is Necessary to Bevel the Edges. The Thickness of the Wall of the Pipe Need Not be More Than the Thickness of Steel Required for the Working Pressure Within the Pipe, Plus a Suitable Allowance for Safety. If Low Carbon Steel Welding Rod is to be Used, the Weld Should be Built Up Twenty-five Per Cent of the Thickness of the Wall. It Will be Noted That the Bevel is Not Carried Clear Through to the Bottom or Internal Surface of the Pipe, But One-sixteenth of an inch is Left Unbevelled. This Prevents Melting Through the Feather Edge Which Would Otherwise Result and the Forming of Drops of Metal on the Inside of the Pipe.

It is possible to weld pipe with an alloy steel of higher tensile strength than the steel of the pipe itself and in this event it is not necessary to build the weld up twenty-five per cent above the surface of the pipe. If an alloy steel rod is used having the proper tensile strength, the weld can be made so that the surface of the weld is almost flush with the surface of the pipe and still give sufficient strength for the purpose of the weld. These are called flush welds and in the report of the American Gas Association heretofore quoted, it is stated that tests made by a large gas and electric corporation showed that flush welds with alloy steel rod produced joints having greater strength than the strength of the pipe.

Welding Rod for Pipe Welding

As the thickness of the metal increases, it is of course necessary to use welding rod larger in diameter. Welding rods are ordinarily manufactured in thirty-six inch lengths and of the following diameters: One-sixteenth, three thirty-seconds, one-eighth, three-sixteenths and one-quarter inches. They can be obtained in other diameters on special orders, but these sizes are ordinarily sufficient for almost all welding work. A larger rod than one-quarter inch would never be used except upon very heavy work.

There is a considerable overlap in the sizes of welding rod used for the various thickness of steel plate, but a fair average is given in the following table:

Diameter of Welding Rod in Inches	Thickness of Steel Plate in Inches
1/16	1/16 and less
3/32	1/16 to 5/32
⅛	3/32 to 5/16
3/16	¼ to 9/16
¼	7/16 to 1 and over

The size of rod used will, of course, depend to a large extent upon the size of the tip and the preference of the welder.

For welding pipe less than one inch in diameter, the three thirty-seconds inch welding rod will suffice, but for welding pipe from one inch up to two inches in diameter, a one-eighth inch diameter rod will be found more satisfactory. The thickness of the rod and the size of the tip is governed by the thickness of the wall of the pipe. The table shown upon page 15, Lesson No. 2, gives the correct thickness of metal for each size of tip. The following table shows the external and internal diameters and circumferences and the thickness of the wall for pipes from one-eighth inch up to two inches in diameter:

Dimensions of Standard Pipe

	Diameters			Circumference	
Size	External	Internal in.	Thickness In.	External In.	Internal In.
⅛	.405	.269	.068	1.272	.845
¼	.540	.364	.088	1.696	1.144
⅜	.675	.493	.091	2.121	1.549
½	.840	.622	.109	2.639	1.954
¾	1.050	.824	.113	3.299	2.589
1	1.315	1.049	.133	4.131	3.296
1¼	1.660	1.380	.140	5.215	4.335
1½	1.900	1.610	.145	5.969	5.058
2	2.375	2.067	.154	7.461	6.494

In order that the thickness of pipe in decimals of an inch may be expressed in fractions of an inch, the following table giving decimal equivalents of fractions of an inch is given:

Frac.	Deci.	Frac.	Deci.	Frac.	Deci.	Frac.	Deci.
1/64	.0156	17/64	.2656	33/64	.5156	49/64	.7656
1/32	.0313	9/32	.2813	17/32	.5313	25/32	.7813
3/64	.0469	19/64	.2969	35/64	.5469	51/64	.7969
1/16	.0625	5/16	.3125	9/16	.5625	13/16	.8125
5/64	.0781	21/64	.3281	37/64	.5781	53/64	.8281
3/32	.0938	11/32	.3438	19/32	.5938	27/32	.8438
7/64	.1094	23/64	.3594	39/64	.6094	55/64	.8594
⅛	.125	⅜	.375	⅝	.625	⅞	.875
9/64	.1406	25/64	.3906	41/64	.6406	57/64	.8906
5/32	.1563	13/32	.4063	21/32	.6563	29/32	.9063
11/64	.1719	27/64	.4219	43/64	.6719	59/64	.9219
3/16	.1875	7/16	.4375	11/16	.6875	15/16	.9375
13/64	.2031	29/64	.4531	45/64	.7031	61/64	.9531
7/32	.2188	15/32	.4688	23/32	.7188	31/32	.9688
15/64	.2344	31/64	.4844	47/64	.7344	63/64	.9844
¼	.25	½	.5	¾	.75	1	1.

These tables will enable the welder to determine quickly the best size of welding rod and tip.

For ordinary pipe welding the most satisfactory welding rod which can be used is a low carbon rod of the analysis shown upon page 14, Lesson

No. 2. As explained heretofore, there are a number of very good alloy steels upon the market which will enable the welding of a joint of even greater tensile strength than can be produced by the low carbon rod. The low carbon rod, however, flows very smoothly and makes a strong, uniform, homogeneous weld. For ordinary purposes the welder will find it a very satisfactory rod.

Other Methods of Welding

The only method of welding described so far in these lessons has been the semi-circular movement method. There are two other important methods, one of which has been termed the advanced flame method, from left to right and the other the advanced flame method of right to left. In the first method, often called the back hand method of welding, the torch is held in the right hand and the welding rod in the left hand, as shown in Figure 12. The weld progresses from left to right. The rod is held in the molten puddle and the torch preheats the metal as the puddle is advanced along the seam. The motion of the rod may be a rolling one, as shown at 1. This movement can be used to advantage upon certain occasions and in this event the rod is not bent. The rod may be bent and moved backward and forward across the puddle, as indicated at 2, or if desired, the rod may describe full circles within the puddle as shown at 3. Some welders find it convenient to move the rod in semi-circles part way around the puddle and back again, as shown at 4. The weld is progressing meanwhile from left to right and the torch is held with the flame still, that is not moving to and fro across the weld, although it may have a very slight motion if desired.

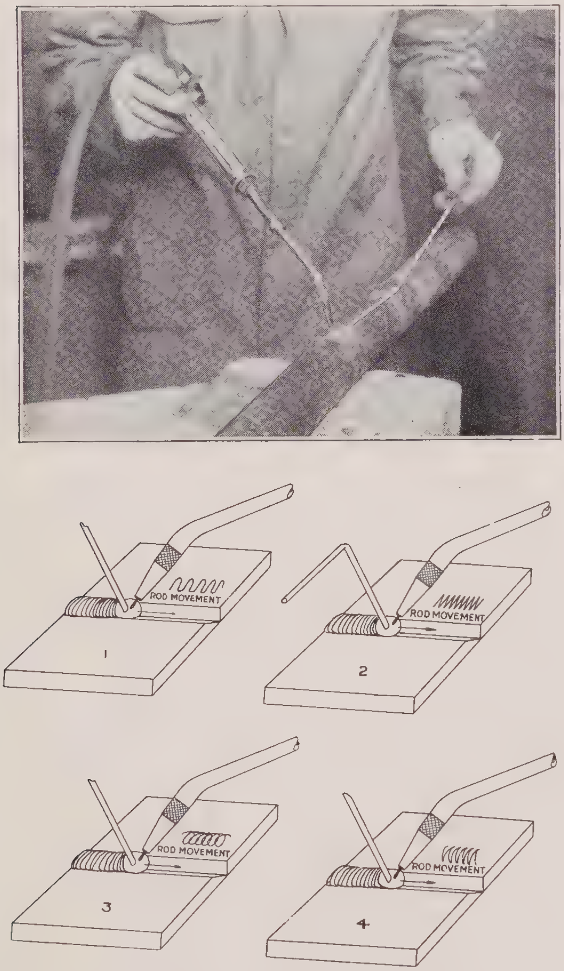


Figure 12—Photograph and Sketches Showing the Advanced Flame Method of Welding From Left to Right. The Flame Precedes the Welding Rod, But the Weld Advances From Left to Right Instead of Right to Left as Heretofore Practiced in These Lessons. This Method is Often Called the Back Hand Method of Welding. The Several Rod Movements are Indicated by the Sketches.

Another variation of this method of welding is to move the torch in semi-circles and the rod straight backward and forward through the puddle, using a rod bent at a right angle, or if the rod is straight it is often convenient to move it in semi-circles through the puddle, alternating with the semi-circular movement of the torch. This method is in reality the semi-circular movement method, but the weld progresses in the opposite direction.

The advanced flame method of welding from right to left is a very excellent method and some welders prefer it, particularly for pipe welding. It has the advantage that penetration through the wall of the pipe is easier to secure and cold shuts caused by flowing the hot puddle over colder metal are not as likely to occur. In this method of welding, the flame precedes the rod, biting down into the metal and melting clear through the section. The flame is held steadily with the torch at a correct angle to accomplish the best results and it is followed by the rod bent at an angle of forty-five degrees and moved to and fro across the puddle. This position is shown in Figure 13 and while it may appear difficult to the welder who has been trained in another way, it is in reality not a difficult movement to master.

The angle of the torch is important, because if it is held pointing too far forward in the direction of welding, the back edge of the puddle is not kept sufficiently hot and the rod is apt to freeze or stick to the cooling rim. If, on the other hand, the torch is straightened up slightly, still pointing forward, but not to as great a degree, it will be found that there is ample room in the molten puddle to the rear of the flame to operate the rod without any likelihood of its sticking to the back rim of the puddle. A little practice will show clearly how this is accomplished. This method of welding may progress in any direction, the flame always preceding the rod. From this it derives the name which has been given to it, the Advanced Flame Method.

Overhead Welding

The student so far has had no experience in overhead welding. If a piece of pipe is to be welded in a fixed position, as it would be in many instances in the erection of pipe about a building, welding must be accomplished horizontally, vertically and overhead. It is not the intention in this lesson that the student shall do much overhead welding as yet, although a little practice at it with a piece of pipe placed above the level of the head would be advantageous. In this lesson it is intended that the pipe shall be rolled as the weld progresses around it and that the pieces of pipe, like the elbows and the tees will be turned to suit the convenience of the welder. After this work has been properly accomplished, it will be time to consider the welding of such joints in fixed positions. A few remarks, however, about overhead welding will be some preparation for this work.

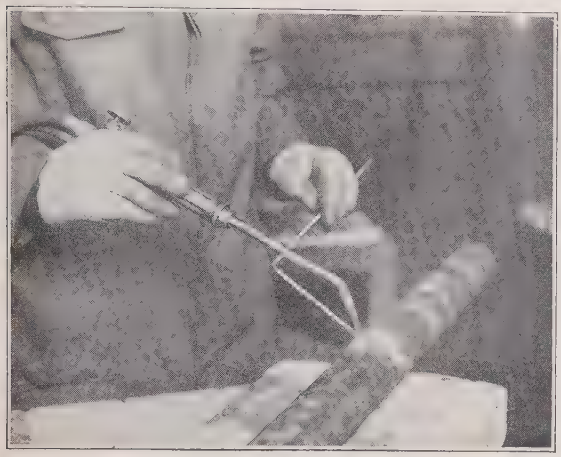


Figure 13—Advanced Flame Method of Welding From Right to Left. This Method is the Opposite of That Shown in Figure 12, With the Additional Advantage That the Flame is Pointed in the Direction of the Progress of the Weld. For this Reason the Flame is Always Preceding the Puddle and Directing the Heat in Advance of the Puddle Into the Break. This is an Excellent Method of Welding and Will be Found Very Advantageous for Many Classes of Work. The Weld May Progress in Any Direction With This Method.

Overhead welding is not as difficult as it appears. It is identically like horizontal welding, except that the position is reversed. In other words, the plate is upside down. All three methods of welding heretofore described are used in overhead welding. Some welders prefer the advanced flame method from left to right and others claim that the advanced flame method from right to left is preferable. The puddle should be kept wide and deep, and the metal should not be melted sufficiently to cause it to fall away in drops from the weld. If it is kept just hot enough and the temperature of the pipe itself and the welding rod are maintained as evenly as possible, the rod will adhere to the metal of the pipe and flow over its surface without dropping down. If the puddle becomes too hot, the torch may be withdrawn momentarily or maintained at a slightly further distance from the weld so that the metal will not become too liquid.

How to Weld a Joint Between Pieces of Two-Inch Pipe

A good supply of scrap two inch black pipe should be available for this lesson. A length of pipe should be selected and marked in sections three inches long. Circumferential lines should be drawn at each of these marks around the pipe, using a piece of leather belt, or a piece of flexible sheet brass having one side straight and using soapstone to mark the pipe. These pieces of pipe should then be cut holding the torch perpendicular to the surface of the pipe. For two inch pipe the No. 0 tip or its equivalent may be used. This tip has a cutting jet port equal to a No. 63 drill and four preheating flames. The acetylene pressure should be five pounds per square inch and the oxygen pressure ten pounds. These are, of course, approximate pressures and the final adjustment should be made at the torch valve.

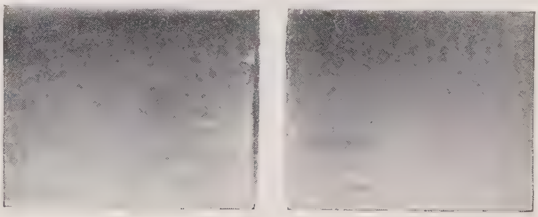


Figure 14—Photograph Showing Two Pieces of Two Inch Pipe Approximately Three and One-half Inches Long, Cut With the Cutting Torch Preparatory to Making a Butt Weld Between Them.

After several three-inch sections have been cut, the oxide should be cleaned away from the edges when the pieces will appear as shown in Figure 14. The two sections should then be butted together, leaving a little space between them to allow for expansion, and tack welded at three points as shown in Figure 15. The space should be about one-half the thickness of the wall of the pipe. One of these thirds of the circumference of the pipe should be placed upward on the welding table and welding begun at the near tack and continued around the pipe to the far tack, or the one furthest away from the operator as he

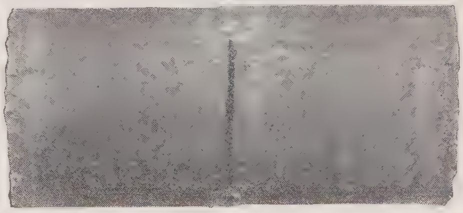


Figure 15—Photograph of Two Pieces of Two Inch Pipe Placed Together With a Slight Space Between Them and Tack Welded at Three Points. Tack Welding Holds the Pipe in Line During Welding.

faces the pipe. The semi-circular movement method, with which the student is already familiar, should be used. When the far tack is reached, the pipe should be rolled towards the operator and the process continued until the weld is completed clear around the pipe. The completed weld is shown in Figure 16.

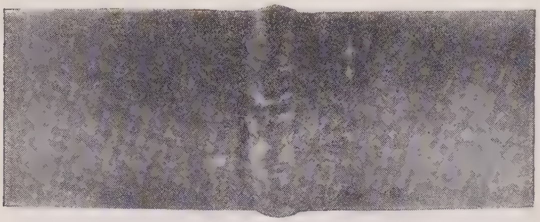


Figure 16—A Completed Butt Weld Between Two Pieces of Two Inch Pipe. Note the Reinforcement of the Weld Above the Surface of the Pipe. A Weld Made in This Manner Has Greater Strength Than the Pipe Itself.

In building up the weld it should be remembered that if low carbon steel rod is used the weld should be reinforced by making the section about twenty-five per cent thicker. The weld is shown in section in Figure 11 for pipe of sufficient thickness to require bevelling of the edges. It is not necessary, however, with two inch pipe to bevel the edges, but the welder should be absolutely sure that fusion takes place clear through the wall of the pipe. This is called penetration of the weld and is one of the most essential features of good welding. It is not only necessary to build a collar of welded metal around the pipe, but actually to fuse the walls of the pipe to their inner surface, and when complete fusion is accomplished to build up the weld to its full section.

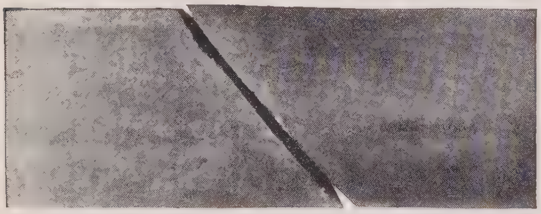


Figure 17—Two Pieces of Two Inch Pipe Cut at an Angle of Forty-five Degrees. This Cut Was Made With the Torch and Afterward Cleaned Up to Make a True Surface to be Welded.

In Figure 17 a photograph is shown of a pipe cut with the torch on a line at an angle of forty-five degrees. In making this cut care should be taken to hold the torch in the plane of the cut, as shown in Figure 4. If this is done and the edges of the cut are fairly smooth, when the two pieces are reversed they will fit together, as shown in Figure 18. They may be tack welded, allowing a little space between these surfaces. The completed weld is shown in Figure 19 and the result is a welded elbow made of two inch pipe. While it is necessary to penetrate the full depth of the wall of the pipe, it is also desirable that there be as little interruption to the flow of gases or liquids through the pipe as possible and for this reason the welder should take particular pains not to melt too deep through the wall of the pipe and leave hanging drops of metal on the inside.

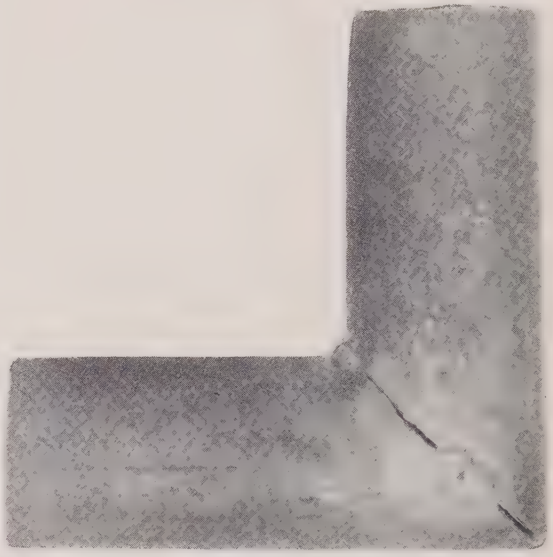


Figure 18—This Photograph Shows Two Pieces of Pipe, Cut as Indicated in Figure 17, and Tack Welded at Four Points. A Slight Space Has Been Left Between the Surfaces to Allow for Expansion.

Figure 20 is a photograph of a completed tee made of two inch pipe. The hole was cut in the side of the two inch pipe with templet sheet No. 7. The end of the branch pipe was trimmed off, as marked by this templet, and the two pieces first tacked and then welded together.

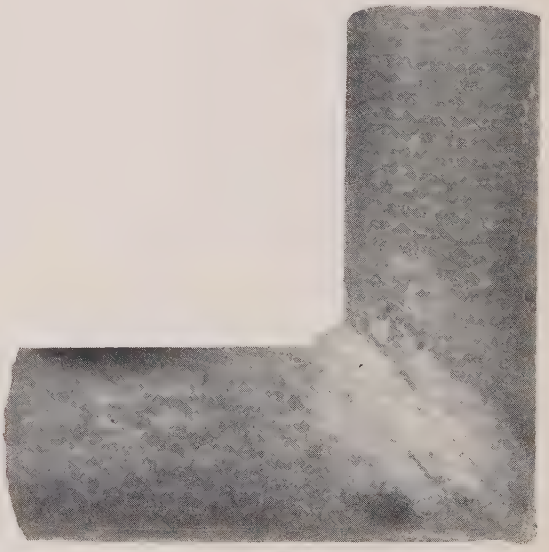


Figure 19—This Photograph Shows the Completed Weld of the Elbow.

Forged Pipe Fittings

Instead of cutting pipe to make various ells, tees, return bends, reducers, etc., forged steel fittings are now being used to a very great extent. These are made by several processes and are furnished in regular pipe sizes with the welding edges already bevelled.

Some of them are called socket fittings because they have a larger opening into which the pipe slips for a short distance. This greatly facilitates lining up the pipe and holding it in place while it is being welded, particularly with the small sizes of pipe.

Forged fittings, in general, provide stronger joints in pipe and the bend causes less resistance to the movement of gases and liquids in the pipe than the more angular joints made by cutting and welding the pipe itself. They are stronger than bent pipe because the wall thickness is uniform throughout. One type of such fittings is called Tube Turns and one of these welded to two straight lengths of pipe is shown in Figure 21. The ends of the pipe are bevelled square and true and, as previously stated, the fittings are bevelled by machine at the factory. This makes welding very convenient and economical. Stresses caused by expansion and contraction are taken care of by the springing of the fitting itself, instead of being dependent largely upon the weld metal, as in the case of an elbow such as shown in Figure 19.

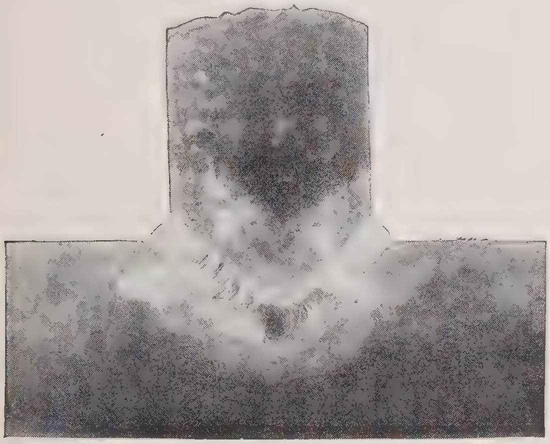


Figure 20—This is a Photograph of a Welded Tee, Cut in the Manner Described, Tacked and Welded.

Forged fittings for all standard diameters of pipe are available and standard sizes for these fittings have been proposed and can be obtained from the American Society of Mechanical Engineers.

Linear Expansion of Pipe

This is a subject which in large pipe becomes a very important one and one which must be compensated for by expansion joints, large radius bends in the pipe, or by some other means. In the small pipe, under consideration in this lesson, however, it is of less importance because of the fact that there is ordinarily sufficient spring in the pipe itself to take care of expansion and contraction strains. The bends and the turns in the pipe line about a small building, or a house where not larger than two inch pipe is used, are sufficiently flexible to take care of normal expansion.

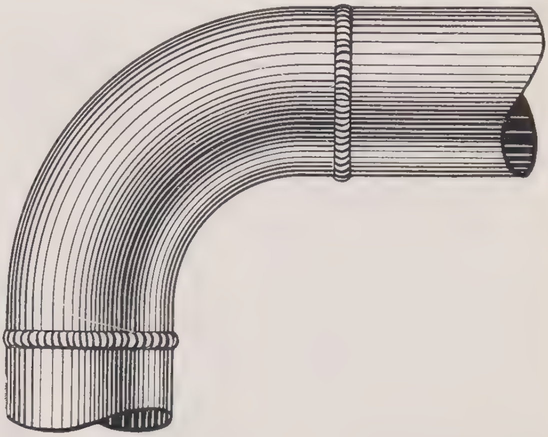


Figure 21—Sketch Showing a Tube Turn and Two Welds Between the Tube Turn and Straight Pieces of Pipe. This Makes an Excellent Ninety Degree Bend Which Causes Less Resistance to the Flow of Liquids and Gases in the Pipe Than Any Other Method of Construction. It is Quickly and Easily Made From a Commercially Produced Tube Turn.

If pieces of pipe, however, are to be welded between two fixed points which are absolutely rigid, then some compensation must be made for contraction which will otherwise place a strain in the pipe. This subject, however, will be taken up in Lesson No. 6 where it becomes more important because of the fact that larger pipe is under consideration.

Protection of Woodwork During the Welding of a Pipe Joint

In welding pipe joints about a building where the framework is of wood, or where a wooden joist or beam might be set on fire, it is, of course, essential that means be taken to protect the woodwork against the heat of the flame. This can be most conveniently done with asbestos paper or board. The heavier grades of asbestos paper are very satisfactory to protect the wall if a piece is slipped in between the pipe and the woodwork and temporarily fastened with a tack or a nail or two. A little care on the part of the welder and the judicious use of asbestos paper will absolutely prevent the injury of any wood or plaster used in the building.

Welding Steam and Hot Water Piping in Homes and Small Buildings

Welded steam and hot water piping is becoming more and more common practice in many cities of the country. As heretofore stated, a welded line which is absolutely tight, can be erected at a lower cost than one constructed of screwed fittings and presents very much less obstruction or resistance to the flow of either the steam or the hot water within the pipe. In hot water heating this is a real economy which will enable the temperature of the water in the system to be raised to full heat in about one-half the time required when ordinary fittings are used.

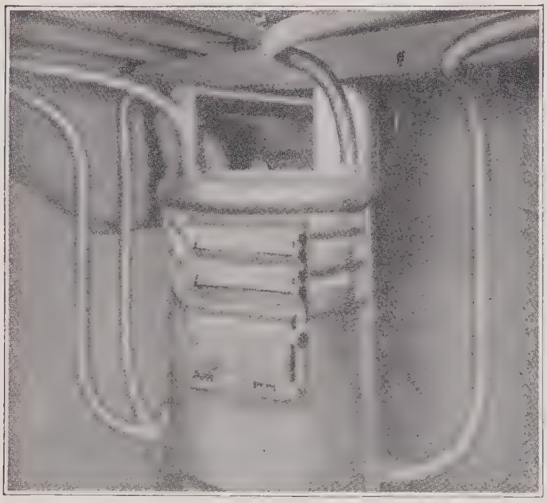


Figure 22—View of a Hot Water Heating Boiler and the Pipe System in a Small Residence. Note the Long Radius Bends on Both the Supply and Return Pipes. These Bends are Made of Bent Pipe Welded and Offer Much Less Resistance to the Flow of Water Within the Pipe.

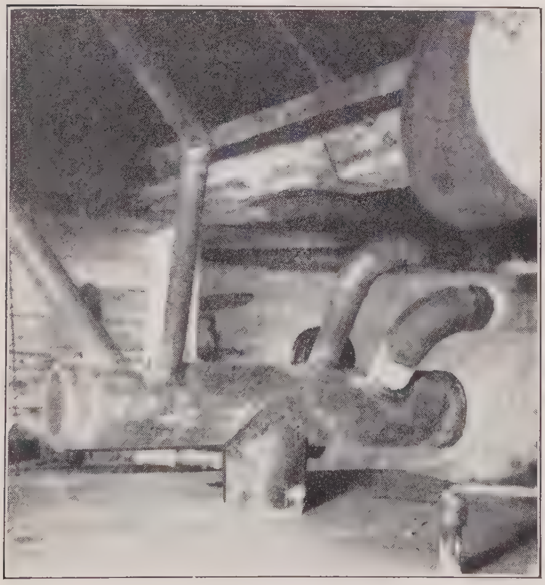


Figure 23—View of a Welded Header on the Top of a Boiler in One of the Larger Residences. Note the Convenience With Which the Branch Pipes are Connected to the Header. Such Construction Would Require Special Castings for Each Installation if Welded Joints Were Not Used.

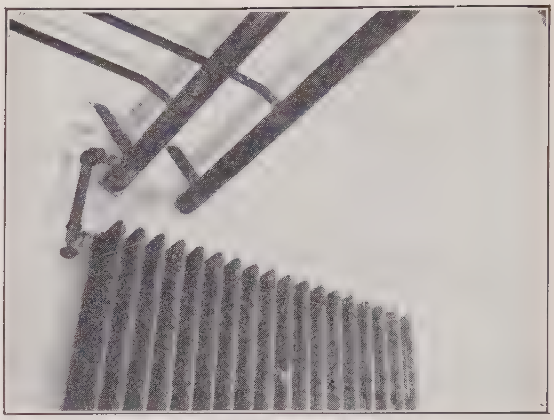


Figure 24—Photograph Showing Two Main Line Pipes With Welded Branches Extending Upward to the Plaster and Along the Ceiling. The Nipple for the Radiator Branch Was Welded to the Header, But the Balance of the Piping Leading to the Radiator Was Made of Screwed Fittings.

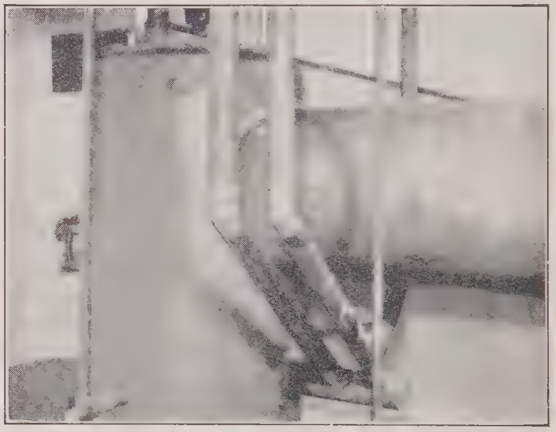


Figure 25—View of a Welded Return Header System of a Heating Boiler in a Residence. Welding Enables the Pipefitter to Erect the System to fit any Local Conditions, even if Limited in Space. The Elbows may be any Angle and Many Different Designs of Headers are Possible.

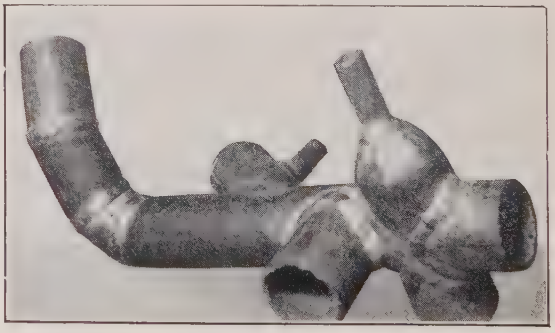


Figure 26—This is An Illustration of the Various Types of Joints Which Can be Made by Welding in Pipe. This Particular Section Was Made to Show How Many Different Welds Could be Accomplished in a Short Length of Pipe.

Job Sheet No. 5

Butt Welding Two Inch Pipe

The welding and cutting equipment required for this exercise consists of the usual tanks of gas, regulators, hose, etc., a welding tip the size of the No. 3 and a cutting assembly with the proper size tip. One-eighth inch welding rod and some two-inch black pipe are also needed.

1. Select a length of two-inch pipe and using a belt or other straight edged, flexible material mark with a piece of chalk or soapstone, a straight line around the pipe about three inches from the end. Next draw another line around the pipe about three inches from the first line.

2. Insert the cutting assembly in the handle, select a tip the size of a No. 0 cutting tip and place in the cutting assembly. If a No. 0 tip is used the regulators should be adjusted so that pressures of approximately five and ten pounds are shown on the acetylene and oxygen working pressure gauges. Light and adjust the flame.

3. Holding the flame in the plane of the cut, in this case perpendicular to the sides of the pipe, carefully cut the pipe along the marks. After the cuts are completed, clean off the slag or oxide which clings to the edges of the pipe by using a cold chisel and hammer.

4. Place two fire bricks an inch apart on the welding table and lay the pieces of pipe just cut, end to end on the crack between the bricks. Adjust the bricks until the pipes are in a straight line with a space of about one-half the thickness of the wall of the pipe between the ends.

5. Remove the cutting assembly from the torch handle and replace with a welding tip the size of a No. 3. Reduce the pressures at the regulators to those shown on the pressure chart, and light and adjust the flame.

6. Tack the two pieces in place by applying the flame to their edges until melted, then add enough metal from the welding rod to cause the edges to flow together. The pieces should be tacked in three places around the circumference so as to hold them rigidly.

7. Turn the pieces so that the space between two of the tacks is uppermost and using one-eighth inch welding rod and the semi-circular torch movement start at the nearest tack and continue forward until the next tack is reached. Then turn the pipe until the following unwelded section is on top and continue in the same manner until the third or last tack is reached, when the work should again be turned so as to place the unwelded portion in a convenient position. This last part is welded in the same manner as the last two portions.

   Care should be taken to make sure that the weld continues uniformly through the points where the tacks were made.

8. Cut off another short piece of pipe and weld to one end of the first two pieces. Continue making these butt welds until able to make a neat, smooth joint. These welds should be built up twenty-five percent of the thickness of the wall as described in the text.

Making a Ninety Degree Y

1. Make a tracing of Templet Sheet No. 8, paste it on a thin sheet of brass or tin, etc., and cut out as previously instructed. The templets to be used for this job are given at the bottom of this sheet.

2. The templet sheet should now be wrapped around the pipe. Care should be taken that the edges of the sheet are parallel, so that the lowermost templet on the sheet is about three inches from the end of the pipe with the point of the curve toward the long end of the pipe. Using a piece of chalk or soapstone mark on the pipe the position of the holes of both of the two lower templets. This will indicate the lines of cut for the end on the main line and the end of one of the branches. Move the templet about three inches further along the pipe and mark, using the next to the bottom templet, the line of cut for the second branch. Now move the templet sheet again and mark a straight line around the pipe, using the end of templet for a guide.

3. The pipe should now be cut along the lines. Be careful to hold the tip of the cutting assembly in the plane of the line to be cut. When the cuts are completed, remove the slag or oxide which may stick to the edge of the cut.

4. Lay the three pieces on the welding table in the position shown in the sketch on the

templet and tack in enough places to hold the pieces in position, then turn them over and tack the other side.

5. Start welding at one of the tacks and turning the pieces when necessary complete welding that seam. Then weld the remaining seam.
6. Choose some other fitting from the sketches shown on the templet sheet and mark off, cut and weld together.
7. These exercises should be repeated until mastered as it is important that the welder be capable of properly executing welds and cuts of this type.

Questions:

1. What advantage has a welded pipe line over a screw fitted pipe line?
2. Why is it not necessary to use as heavy pipe for a welded line?
3. What is a butt joint?
4. Is it necessary to prepare the edges of pipe in any way before welding?
5. When cutting pipe, how should the flame be directed?
6. What is the purpose of a templet?
7. Make a free hand sketch of the manner in which the templet for cutting pipe to form a sixty degree elbow is made.
8. Describe the two types of advanced flame welding.
9. What is a tube turn?
10. How is it possible to prevent injury to walls, etc., when installing welded pipe systems?

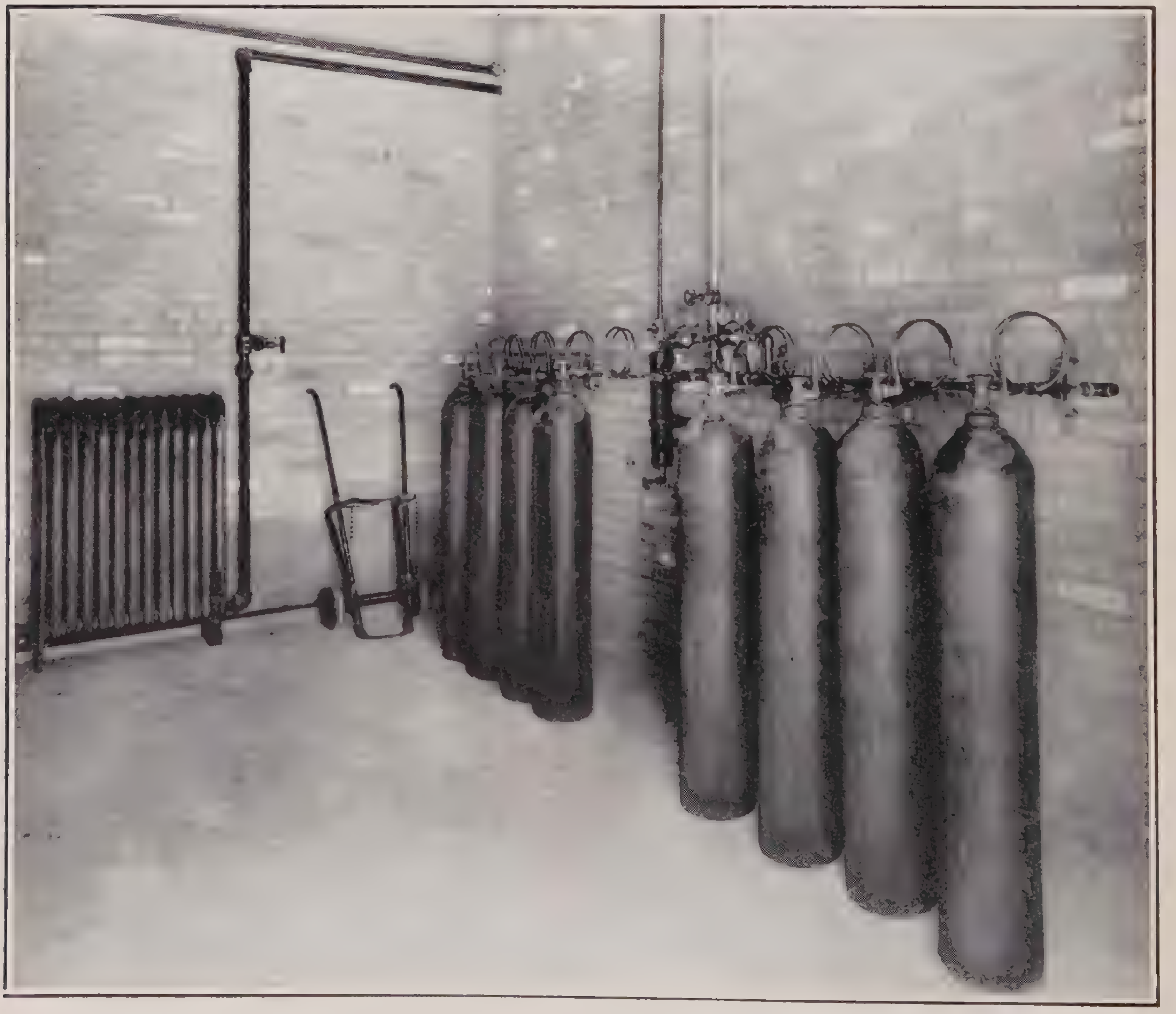


Figure 27—Interior View of the Oxygen Manifold Room of the Gas House Shown on Page 40. Considerable Space Has Been Made Available for the Storage of Oxygen Cylinders.

Lesson No. 6

Welding Large Diameter Pipe Lines

THE first subject to be considered in this lesson is the expansion and contraction of steel during the welding operation. Expansion and subsequent contraction are always serious factors in heating metal. They are not so serious with steel or iron as with cast iron for the simple reason that either iron or steel will stretch to a certain extent while cast iron does not stretch at all. Both metals of course, if strained beyond their strength will break. Therefore, in welding steel in spite of its elasticity, it is essential that provision be made to eliminate strains as far as possible, either in welding sheet steel or in welding pipe.

Expansion and Contraction

Nothing has been said as yet about the expansion of a seam being welded and no provision has been made for this expansion, because all of the welds which have been attempted so far have been made in comparatively short pieces of steel. These pieces were not long enough to cause difficulty by overlapping. If, however, a long seam is to be welded, it is essential that provision be made for the expansion of the metal while being welded and its subsequent contraction when it cools. For instance, in Figure 1 a tank seam is shown in steel more than three-sixteenths of an inch in thickness. The edges have been bevelled to an included angle of ninety-degrees, and these edges at the end of the seam toward the reader have been separated one-sixteenth of an inch as shown in Figure 2. If both the near and the far ends of the seam were securely tack welded after the edges had been placed in contact with each other and welding of the seam were started at the near end and progressed toward the far end, the metal would expand as it became heated. Expansion would cause the edges to crowd each other more closely as they became hotter and as they could not push each other out of the way, one edge or the other would warp up or down. In this manner the interference of the opposing sheet or plate is overcome and the metal warps from resisted expansion.

Under such circumstances welding becomes difficult if not impossible and the resultant welded seam is so badly warped out of shape as to be, in most instances, useless for any practical purpose. To obviate or prevent this tendency of one of the sheets to climb over and lap the other, the far ends of the seam are placed a certain definite distance apart to allow for the expansion of the metal as the weld progresses. This distance is usually two and one-half per cent of the length of the seam, or approximately one-quarter inch to every foot of length. This is clearly indicated in Figure 2.

It is usually convenient in welding such a seam to tack weld the near end of the seam after it has been separated one-sixteenth of an inch. The far end of the seam in the meantime is kept apart the right distance with a clamp made of two pieces of plate and a bolt as shown in Figure 3. The object of the clamp is not to prevent the far edges from coming together at the right time, but rather to keep the plates in alignment as the weld progresses, that is, to prevent their warping one above the other out of their ordinary plane. As the weld progresses along the seam the edges will expand and the far ends of the plates will approach each other until when the weld approaches the far end of the seam the edges will be almost in contact.

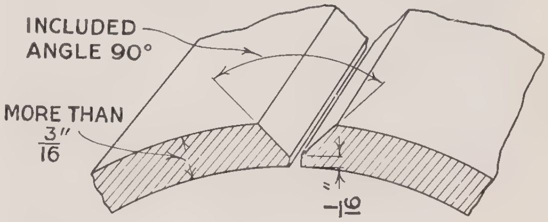


Figure 1—Sketch Showing the Preparation of the Edges of the Longitudinal Seam of a Tank. If the Thickness of the Metal is More than Three-sixteenths of an Inch, the Edges Should be Bevelled to an Included Angle of Ninety Degrees Within One-sixteenth of an Inch of the Bottom of Each Sheet. This is an Enlarged View of the End of the Seam Nearest the Reader Shown in Figure 2.

Tack Welding Large Pipe

In this lesson the welding of large diameter pipe is under consideration. The seams to be welded are the circular seams between the ends of the pipe lengths. In welding a pipe the situation is a little different from that which exists when welding a long seam between two pieces of plate. It is necessary, however, to compensate for the expansion in welding a seam of this kind, but this compensation is accomplished in a different way. It would, of course, be impossible to separate the seam as with plates and for this reason when welding large pipe of, for instance, twenty inches in diameter, the ends of the bevelled pipe are placed together so that they are approximately one-quarter inch apart all the way around the circumference.

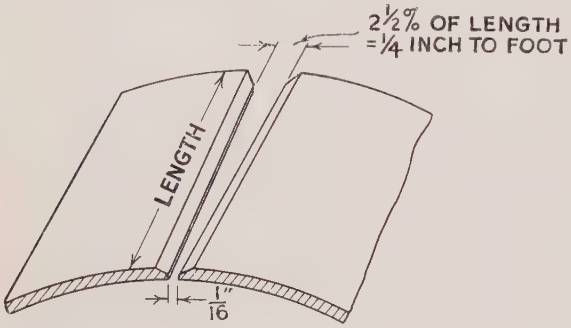


Figure 2—The Near Edges of the Seam Should be Separated One-sixteenth of an Inch and the Far Edges Two and One-Half Per Cent of the Length of the Seam, or Approximately One-quarter Inch Per Foot. In Other Words, If the Length of the Seam Were Ten Feet, the Edges of the Metal at the Far End of the Seam Would be Separated Two and Nine-sixteenths Inches. The Near End of the Seam Should be Tack Welded and the Far End Held in Position by a Clamp, Similar to That Shown in Figure 3.

The two lengths of pipe are then tack welded at eight points around the outside surface, each of the tack welds being about one inch in length. This is clearly indicated in Figure 4. The upper sketch, Figure 4, is a cross section A, B, looking at the end of the pipe. The lower sketch is a vertical section through the center line of the pipe, showing tack welds Nos. 1 and 2 at the top and bottom of the pipe and Nos. 5, 3 and 8 on the far side of the pipe. The three tack welds on the near side of the pipe do not show in this section.

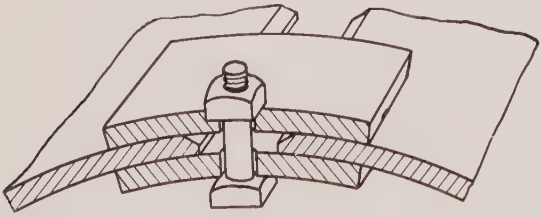


Figure 3—A Convenient Plate and Bolt Clamp Which Can be Used to Keep One Edge of a Long Seam in a Tank from Attempting to Climb Over the Other. If Not Screwed Too Tight, the Expansion of the Metal As the Weld Progresses Along the Seam Will Bring the Sheets or Plates Nearer Together Until They Finally Meet.

If the tacks were all made on one side of the pipe this side would be made very hot, while the opposite side would remain cold, with the result that the pipe would be thrown out of alignment. To avoid this condition, tack welds should be made at opposite sides of the pipe if possible by two welders working simultaneously. For instance, if there were two welders available, one man would make tack weld No. 1, Figure 4, while the other welder was making tack weld No. 2. No. 1 welder would then make tack weld No. 3 and No. 2 welder tack weld No. 4, and so on, each welder working at opposite sides of the pipe simultaneously. If only one welder were available, he would make tack weld No. 1, then 2, then 3, then 4, and so on, as indicated in the upper sketch of Figure 4. It will be readily appreciated that in this way the effect of the expanding metal as it is heated is minimized and distributed around the pipe. The result will be much better alignment of the pipe without the tendency of one part of the pipe to crowd the other.

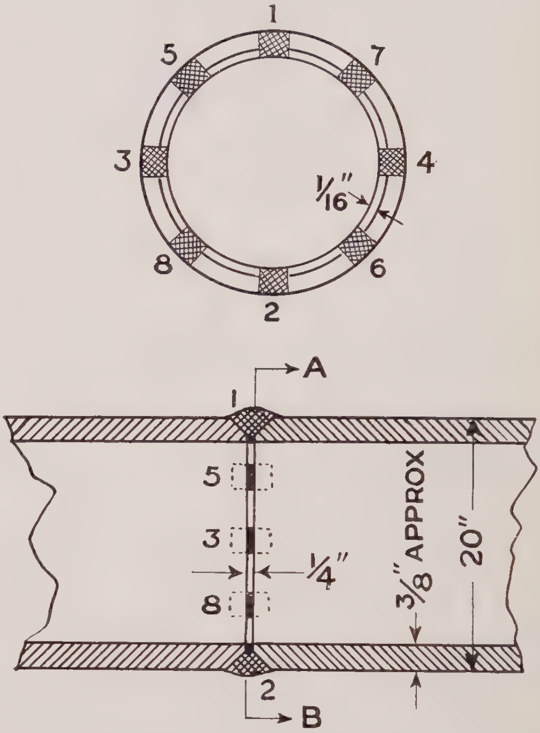


Figure 4—The Cross Section A B Shows the Sequence of Tack Welding a Seam Between Two Lengths of Twenty Inch Pipe. To Compensate for Expansion and Contraction and to Keep the Pipe in Alignment, This Sequence is Essential. The Tack Welds are Made as Numerically Shown. The Vertical Section Through the Center of the Pipe Shows the Upper and the Lower Tack Welds and Those Appearing on the Far Half of the Pipe.

Welding Pipe During Continuous Turning

There are several methods of welding and these automatically take care of the expansion of the metal as the weld progresses. In fact, they have been developed to compensate as far as possible, or adjust the expansion so that it will be distributed around the entire circumference. The sketch, Figure 5, illustrates the positions of the torch and rod and the method of welding twenty inch pipe when it is possible to turn the pipe all the way round. In this case several welders are assigned each to a specific joint and two or more men are equipped with tongs to turn the pipe as the weld progresses. The pipe is set on roller supports so that it may be turned easily. In this case welding begins at one of the tacks and is carried on always on top of the pipe, that is, in the upper portion of the circumference in a position convenient for the welders.

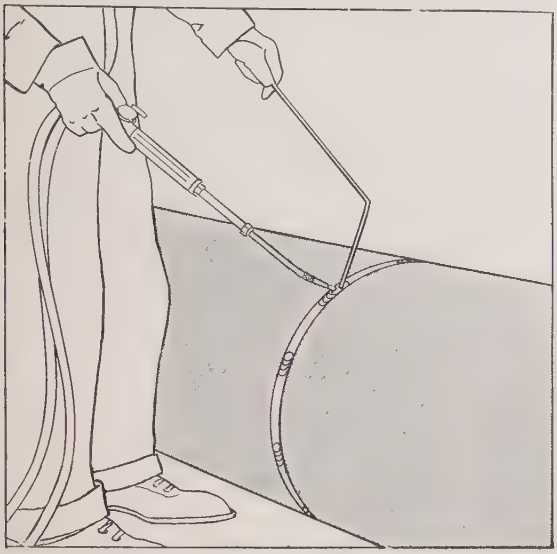


Figure 5—Sketch Showing the Position of the Welding Rod and the Torch in Making a Weld Between Two Lengths of Pipe Which can be Turned Continuously Until the Weld is Finished. Usually Several Lengths of Pipe are Tack Welded Together and a Welder Started at the Top of Each Seam. The Pipe is Turned at the Signal of the Head Welder, so that All of the Men are Always Working on the Top of the Pipe and in This Manner the Weld Continues until Entirely Around the Circumference of the Seam.

The weld should climb or progress up the inclined circumference towards the top rather than over the top and on down the circumference, or down hill. The reason for this is that in welding up an incline, the puddle is easier to control than it would be if the weld inclined downward. In crossing a tack weld, the tack weld metal should be fused and the weld remade. In this manner the weld progresses all the way around the pipe, the pipe being turned at the signal of the head welder, until the entire circumference is completed. In joining in the weld to the point of beginning, the metal of the weld already made should be heated to a dull red for about three inches beyond the junction point. This will assist in normalizing the metal at this point and in avoiding strains.

A weld in a pipe may be made using the semicircular movement from right to left in which case the pipe would be turned from left to right. The advanced flame method from left to right may be used and the pipe turned in the opposite direction from right to left. It is also strongly recommended by many welders that the advanced flame method from right to left, where the torch points in the direction of the weld and the torch precedes the welding rod, be used for pipe welding. It is believed by them that this method is more economical than any other method of welding, because the position of the flame enables the welder to heat the seam ahead of the puddle to better advantage than in any other manner. The claim is made also that this method utilizes the heat from the burning envelope of the flame to better advantage. There are, however, many good pipe welders who use either one or several of these methods to advantage. It is more largely a matter of skill on the part of the operator. Skilful manipulation of the torch is of more importance than the routine in which the torch is manipulated.

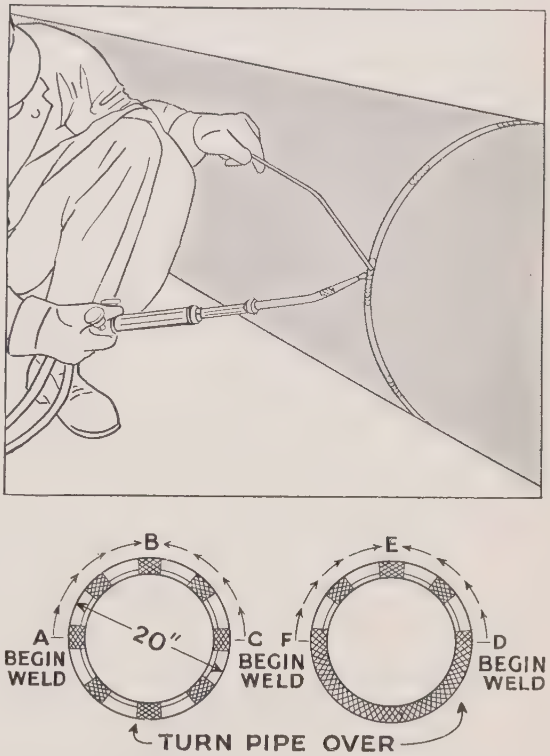


Figure 6—Sketches Showing Method of Welding Pipe When the Pipe is to be Turned Over Only Half Way. The Weld Should be Begun, If there is Only One Welder, at A and Continued to the top, B; then started again at C and Continued Upward to the Top, B. The Pipe Should then be Turned Half Way Over and the Weld Begun at F and Continued Upward to the Top, E and again at D and Continued Upward to the Top, E. If Two Welders are Available Both Should Start Simultaneously at A and C and Weld Upward to the Top, B. The Pipe Should Then be Turned and Simultaneous Welds Made from the Sides, D and F, to the Top, E.

The minimum width of weld should be two and one-half times the thickness of the pipe. This allows for the space left between the end of the pipe, the space taken up by the bevel and a little more width to assure that the edges of the weld metal, where it joins the metal of the pipe, are thoroughly fused.

Welding by Turning Pipe Once Over

Another method of pipe welding is illustrated in Figure 6. If two welders are available, each welder begins simultaneously at opposite sides of the pipe after it has been tack welded as heretofore described. Each welder welds from the side of the pipe up to the top, or in other words, from the two side points A and C upward to the point B. The pipe is then turned over and the two welders weld from D and F respectively upward to the point E, both working simultaneously. If only one welder is available, he begins at the side point A, Figure 6, and welds upward to the point B, he then starts at C and welds upward to the point B. The pipe is then turned over and he starts at D and welds upward to E and then at F and welds upward to E.

Stationary Welds

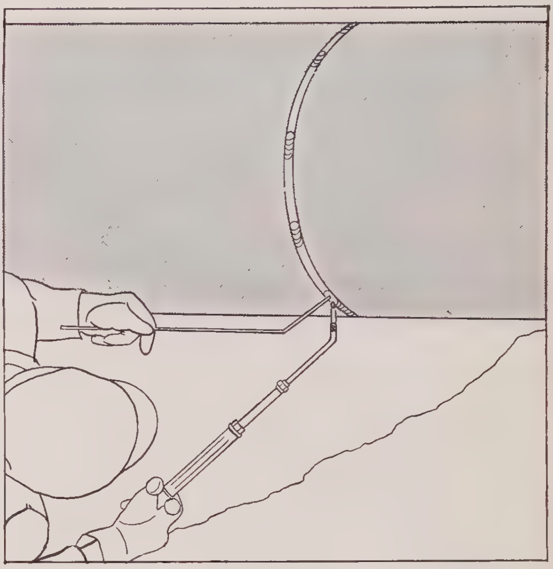
It is evident that the number of lengths of pipe which can be welded together by turning, before a weld is made where the pipe cannot be turned, depends entirely upon the contour of the ground. In some cases quite a good many lengths can be welded before a stationary weld must be made, and in some other cases, it is essential to make a larger number of stationary welds. A stationary weld is one made between that portion of the pipe which has already been welded and cannot be turned and the new section of pipe where a number of lengths have been welded together by turning. The new, long length of pipe is aligned in position with the completed pipe line and a hole is dug underneath the joint so that the welder can conveniently get at the lower part of the seam.

If possible, welding should be done by two welders working simultaneously. One from one side of the pipe and the other from the other side. Both begin at the bottom of the pipe and weld simultaneously upward each completing half of the seam to the top. If only one welder is available for this purpose, he should begin at the bottom of the seam and complete one-half of the weld, then begin again at the bottom and continue around to the top of the other half. It is, of course, presupposed that all of these joints are tack welded, as has been described, before permanent welding is accomplished. In all cases, of course, the weld is built up to a thickness twenty-five per cent greater than the thickness of the pipe wall, as shown in Figure 8.

These methods clearly indicate that, as far as possible, the heat caused by welding is distributed around the circumference of the pipe. In other words, no one portion of the pipe is allowed to become so hot that it warps out of plane, or otherwise becomes difficult to control.

Linear Expansion of Pipe

It will be realized that the discussion so far has been entirely upon the controlling of expansion, while a seam between two lengths of pipe was being welded. Nothing has been said about the



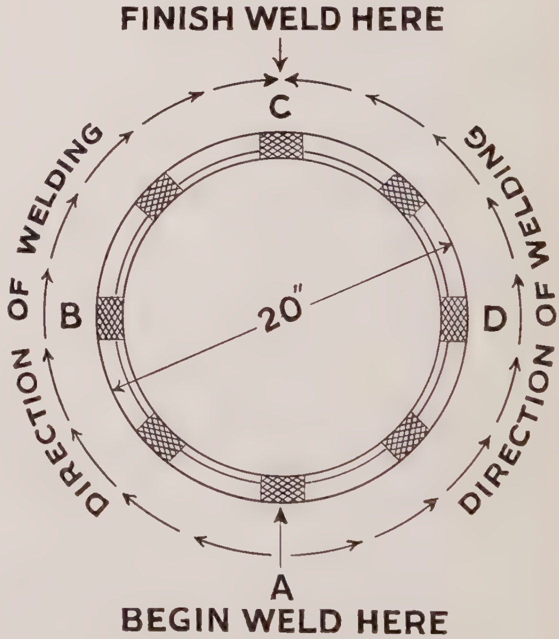


Figure 7—When the Pipe Cannot be Turned, For Instance, When a New Section of Several Lengths of Pipe Which have been Welded by Turning Are to be Welded to a Section Already in the Ground, a Stationary Weld Must be Made. If Two Welders are Available, Each Should Begin at the Bottom of the Seam After It Has Been Tack Welded, as Described, and the Weld Continued Simultaneously Around Each Side to the Top, Both Welders Finishing at the Top. If Only One Welder is Available, He Should Begin at the Bottom and Weld Around One side to the Top, as A, B, C. He Should then Begin Again at the Bottom A and Weld Around A, D, C to the Top.

linear expansion of the pipe which would take place for instance if the pipe were welded, as is often the case, when the temperature is from eighty to one hundred degrees and where the winter temperature in the same locality might cause the temperature of the pipe to drop as low as thirty-five or forty degrees if the pipe were buried. Often there are cases where the pipe is laid on top of the ground and in such instances the extreme between the temperature at which the pipe line was constructed and the low winter temperature covers a very considerable range.

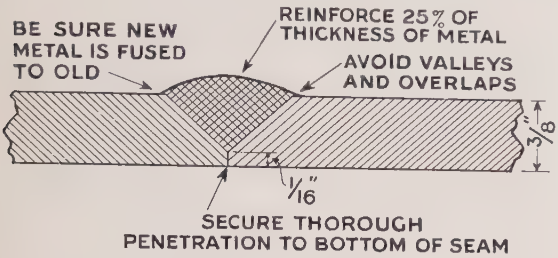

BE SURE NEW METAL IS FUSED TO OLD
REINFORCE 25% OF THICKNESS OF METAL
AVOID VALLEYS AND OVERLAPS
3/8"
1/16"
SECURE THOROUGH PENETRATION TO BOTTOM OF SEAM

Figure 8—Sectional View Through a Butt Weld in a Twenty Inch Pipe. This Shows the Typical Bevel, the Reinforced Weld and the Required Penetration Clear Through to the Inside of the Wall.

Every degree of change in temperature causes a pipe line to contract, or expand, depending upon whether the change is down the temperature scale or up. If the temperature change is down, each one degree will tend to shorten the line and this tendency to become shorter places a strain upon the metal equal to approximately two hundred pounds per square inch. The linear expansion or contraction of a pipe line is a very serious factor and must be taken care of in some manner. With oil or gas lines the maximum change in temperature lies between the temperature when the line was laid and the low winter temperature of the district. With steam lines, however, the change is even greater. The steam will cause the pipe to be excessively hot and when a pipe line is shut down in the winter time it may become very cold. The linear expansion of iron and steel pipe has been determined by experiment and can be found in almost any engineering handbook. It is the same no matter what the diameter of the pipe and is given in the following table:

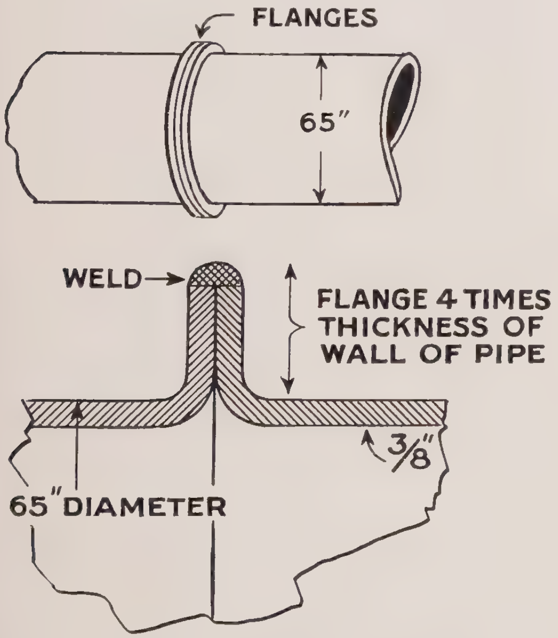


Figure 9—Sketches Showing a Flanged Joint in Large Diameter Pipe, Where the Pipe is Flanged and Welded, as Shown in the Section.

Table Showing the Increase in Length of a Pipe Line in Inches Per 100 Linear Feet

Temperature Degrees F.	Wrought Iron	Steel
0	0	0
20	.15	.15
40	.30	.30
60	.45	.45
80	.60	.60
100	.80	.75
120	.95	.90
140	1.15	1.10
160	1.35	1.25
180	1.50	1.45
200	1.65	1.60
220	1.85	1.80
240	2.05	2.00
260	2.20	2.15
280	2.40	2.35
300	2.60	2.50
320	2.80	2.70
340	3.05	2.90
360	3.25	3.05
380	3.45	3.25
400	3.65	3.45
420	3.90	3.70
440	4.20	3.95
460	4.45	4.20
480	4.70	4.45
500	4.90	4.70

It is evident from this table that the change in length of a pipe line one thousand feet in length during a change in temperature from zero to one hundred degrees would be, if the pipe were steel, seven and one-half inches. This is a very considerable change and if the pipe where unable to move, that is, if each end were absolutely fixed in position, the strain placed upon the pipe would be two hundred pounds for each degree, or 20,000 pounds per square inch for one hundred degrees. This is a very considerable strain, but in all probability not nearly enough to break the pipe. As a matter of fact, the change is rarely as much as one hundred degrees, because in most instances pipe is buried below the frost line and does not get as cold as it does on the surface in the colder climates. The breaking strength of the steel from which pipe is made is normally about 50,000 pounds per square inch.

Strains Should Be Compensated

It is, however, essential in the laying of a pipe line that all strain, due to contraction and expansion, be compensated as far as possible in some way, either by a special joint or in some other manner. The compensation ordinarily made in long lines of pipe, such as oil and gas lines extending across the country, is accomplished by snaking the pipe along the surface of the ground, or in the trench. These S shaped changes in direction of the pipe line permit the metal to expand and contract without placing a severe strain upon the line itself. In other words the pipe line bends slightly and is not strained lengthwise.

In almost all pipe lines the butt weld, bevelled as shown in Figure 8, and reinforced twenty-five per cent more in thickness than the thickness of the wall of the pipe is common practice. As stated in Lesson 5 for pipe up to about 20 inches in diameter, it has proved to be the most satisfactory joint for oil and gas high pressure lines, as well as those made for steam and other purposes.

Butt and Flange Welding Large Diameter Pipe Lines

Another field for pipe welding, however, has been more recently developed and that is the welding of very large diameter pipe, for instance, pipe sixty-five inches in diameter with a thickness of wall of three-eighths of an inch; or pipe forty-two inches in diameter with a wall thickness of five-sixteenths of an inch. When a butt weld is used the problems of expansion and contraction are very serious in such large diameter pipe and must be taken care of in some manner quite different from the means ordinarily applied to the smaller diameter pipe of perhaps twenty inches where the wall thickness is just as great as in the larger pipe.

After some unfortunate experiences upon large diameter pipe in California, engineers have suggested a flanged joint, such as illustrated in Figure 9. This type of joint involves flanging out the end of the pipe to a width approximately four times the thickness of the metal and making a weld between the edges of the flanges. This is a relatively easy weld to make, in fact, easier than the butt weld and does not heat the body of the pipe to as great an extent. Furthermore, it provides sufficient stretch at the flanges to take care of linear expansion adequately. While flanged joints in large diameter pipe are yet too new to furnish much actual experience under construction conditions, at the same time it would appear that such a joint would satisfactorily overcome the difficulties encountered in the California line.

Dimensions of Standard Pipe

The following table gives the nominal size of pipe in inches from two and one-half to twelve inch pipe. It also gives the external and internal diameters, the thickness of the wall in inches and the external and internal circumferences.

	Diameter			Circumference	
Size Inches	External Inches	Approximate Internal Inches	Nominal Thickness Inches	External Inches	Internal Inches
2½	2.875	2.469	.203	9.032	7,757
3	3.500	3.068	.216	10.996	9.638
3½	4.000	3.548	.226	12.566	11.146
4	4.500	4.026	.237	14.137	12.648
4½	5.000	4.506	.247	15.708	14.156
5	5.563	5.047	.258	17.477	15.856
6	6.625	6.065	.280	20.813	19.054
7	7.625	7.023	.301	23.955	22.063
8	8.625	8.071	.277	27.096	25.356
8	8.625	7.981	.322	27.096	25.073
9	9.625	8.941	.342	30.238	28.089
10	10.750	10.192	.279	33.772	32.019
10	10.750	10.136	.307	33.772	31.843
10	10.750	10.020	.365	33.772	31.479
11	11.750	11.000	.375	36.914	34.558
12	12.750	12.090	.330	40.055	37.982
12	12.750	12.000	.375	40.055	37.699

These figures will be found useful in connection with the templets and as a means to select the proper size tip for the size pipe to be cut and welded.

Above twelve inches pipe sizes are specified according to the outside diameters and not the inside diameters as is the practice with pipe twelve inches and less. The following table gives the outside diameters under the heading "Size" and the external and internal diameters and the thickness of the pipe for what is known as "National" Line Pipe.

Size Inches	External Diameter Inches	Internal Diameter Inches	Thickness Inches
14 O. D.	14.000	13.250	.375
15 O. D.	15.000	14.250	.375
16 O. D.	16.000	15.250	.375
17 O. D.	17.000	16.214	.393
18 O. D.	18.000	17.182	.409
20 O. D	20.000	19.182	.409

The welder may encounter other thicknesses of pipe and larger diameters than twenty inches, but in such cases it is quite likely that the specification for the pipe would be special to cover the particular requirements of the job and would not allow standard dimensions. These large diameter pipes can be obtained with various thicknesses of wall to suit the particular requirements for the work and the internal pressures for which they are to be used.

For the convenience of the student, the table giving the decimal equivalents of fractions is repeated in this lesson. It is as follows:

Frac.	Deci.	Frac.	Deci.	Frac.	Deci.	Frac.	Deci.
1/64	.0156	17/64	.2656	33/64	.5156	49/64	.7656
1/32	.0313	9/32	.2813	17/32	.5313	25/32	.7813
3/64	.0469	19/64	.2969	35/64	.5469	51/64	.7969
1/16	.0625	5/16	.3125	9/16	.5625	13/16	.8125
5/64	.0781	21/64	.3281	37/64	.5781	53/64	.8281
3/32	.0938	11/32	.3438	19/32	.5938	27/32	.8438
7/64	.1094	23/64	.3594	39/64	.6094	55/64	.8594
⅛	.125	⅜	.375	⅝	.625	⅞	.875
9/64	.1406	25/64	.3906	41/64	.6406	57/64	.8906
5/32	.1563	13/32	.4063	21/32	.6563	29/32	.9063
11/64	.1719	27/64	.4219	43/64	.6719	59/64	.9219
3/16	.1875	7/16	.4375	11/16	.6875	15/16	.9375
13/64	.2031	29/64	.4531	45/64	.7031	61/64	.9531
7/32	.2188	15/32	.4688	23/32	.7188	31/32	.9688
15/64	.2344	31/64	.4844	47/64	.7344	63/64	.9844
¼	.25	½	.5	¾	.75	1	1.

Pipe can be obtained from the mill with the edges bevelled ready for welding. In most instances upon large pipe lines the pipe is ordered from the mill with the edges already bevelled to angles of forty-five degrees which, when placed together, form an included angle of ninety degrees. An example of this bevelling is shown in detail in Figure 8. Such bevelling greatly assists the welder in the field and avoids the necessity for his cutting the edges of the pipe to a bevel. It then only becomes necessary to bevel the pipe with the cutting torch when a section has been cut where some particular fitting must be placed at a given point and one of the lengths of the pipe must be cut off to accommodate this local condition.

Instruction of Welders

It is very important on any pipe line job that the men employed be thoroughly skilled in steel welding before attempting actual work upon the line. Many welders who have had more or less practice upon other classes of work believe that they are skilled pipe welders, but that they are skilled should be definitely known before the men are placed at work. Perhaps the most efficient way in which this can be definitely proved is to take, for instance, two pieces of pipe of the same diameter and thickness as that to be placed in the line and bevelled in the same manner. These two pieces of pipe should be set up by the welder and if he is to be attached to the gang who are welding by turning the pipe, his test weld should be made in similar manner. If he is to be placed in the gang making stationary welds he should make the test weld in a stationary position. The foreman should check the time required to make the test welds to be sure that the men are sufficiently experienced to weld economically.

The cutting torch should be used to cut out a specimen section of the test welded joint from one and one-half to two inches in width and from eight to ten inches in length including the weld. The weld should be in the center of this section cut out of the pipe. Another section should be cut from the pipe at the point where the weld started and was finished. This section should include this junction point at about the middle of the section. These welded specimens should be put in a vise with the weld adjacent the vise jaws and the top of the weld facing the forward part of the vise.

With a sledge hammer, this section should be bent over at right angles toward the rear of the vise and this should be accomplished without breaking the weld. The specimen should be bent back and forth in this manner until it finally breaks. It will break either outside of the weld or in the weld. If it does break in the weld, the weld metal should be carefully examined to determine that there are no gas pockets, cold shuts or inclusions of slag that would account for weakness. If a welder can pass this test, there is little doubt that he has sufficient skill to enable him to weld successfully on the construction of the pipe line.

Organization of Welding Forces

As a rule in laying long pipe lines the crew of men is divided into four gangs. The first of these gangs rolls the lengths of pipe into position, places these lengths on skids and lines them up ready to be tack welded. The second gang moves the lengths of pipe either backward or forward, as may be necessary, so that the space between these lengths and the alignment is correct and tack welds the joint as heretofore described. The third gang welds the pipe together by turning as many lengths of pipe as the contour of the ground will permit. The fourth gang makes the necessary stationary welds between the lengths of pipe welded by the third gang and the long welded pipe line already completed. They also snake or bend the pipe from one side of the trench to the other or upon the surface of the ground and take care of any larger permanent bends which have to be made because of the irregular grade of the ditch or the surface.

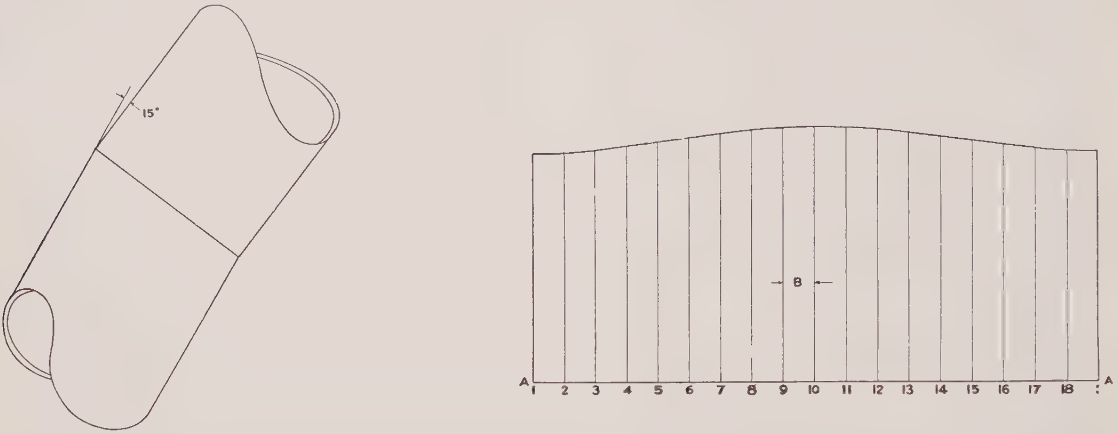
Welding Long Lines of Pipe

The welding of many miles of long pipe line, particularly of large diameter, is a task requiring good engineering practice and a very thorough knowledge of welding. Ditching is done either by hand or wherever possible by a ditching machine. The bottom of the trench should be graded if necessary and any obstructions, like boulders or sections of bed rock, should be removed and the grade of the bottom of the ditch made as level and solid as possible. After the pipe is welded on the surface, it is rolled into the ditch, if small pipe, or lowered with windlasses or chain falls, if large in diameter.

Pipe lines should be covered with some sort of protective coating, either asphaltum paint or some other suitable, corrosion resisting material. The snaking or forcing of the pipe from side to side in the trench is very important and as much slack as is possible should be placed in the line in this manner.

Contraction can also be compensated for by making some of the stationary welds, either on a cool day or in the early morning when the temperature is lower than during the middle of the day.

Table Giving Data For Cutting Pipe to Form a 15 Degree Single Weld Elbow



Shape Assumed by the Completed Templet and Elbow Produced by It.

Size Pipe Inches	Outside Diam. Inches	Dist. B Inches	Length of Base Line A	Length of Ordinates For Single Weld, 15 Degree Elbow									
				1	2, 18	3, 17	4, 16	5, 15	6, 14	7, 13	8, 12	9, 11	10
2½	2.875	.5017	9.032	4.50	4.52	4.54	4.60	4.66	4.73	4.79	4.84	4.87	4.89
3	3.500	.6110	10.996	4.50	4.52	4.56	4.63	4.70	4.79	4.86	4.92	4.96	4.97
3½	4.000	.6981	12.566	4.50	4.52	4.56	4.64	4.72	4.82	4.90	4.97	5.01	5.03
4	4.500	.7854	14.137	4.50	4.53	4.57	4.65	4.75	4.87	4.97	5.05	5.10	5.12
4½	5.000	.8727	15.708	4.50	4.53	4.58	4.66	4.77	4.89	5.00	5.13	5.15	5.16
5	5.563	.9709	17.477	4.50	4.54	4.60	4.70	4.81	4.94	5.06	5.16	5.22	5.25
6	6.625	1.1563	20.813	4.50	4.54	4.60	4.72	4.86	5.02	5.15	5.28	5.35	5.37
7	7.625	1.3308	23.955	4.50	4.54	4.62	4.76	4.93	5.12	5.27	5.41	5.50	5.53
8	8.625	1.5053	27.096	4.50	4.54	4.63	4.79	4.98	5.18	5.37	5.52	5.63	5.67
9	9.625	1.6799	30.238	4.50	4.54	4.66	4.83	5.05	5.27	5.49	5.66	5.77	5.82
10	10.750	1.8762	33.772	4.50	4.54	4.67	4.87	5.12	5.39	5.63	5.83	5.97	6.01
11	11.750	2.0508	36.914	4.50	4.55	4.69	4.90	5.15	5.43	5.68	5.89	6.04	6.09
12	12.750	2.2253	40.055	4.50	4.55	4.70	4.92	5.20	5.50	5.78	6.01	6.14	6.20
14	14.000	2.4434	43.982	4.50	4.55	4.71	4.96	5.27	5.60	5.91	6.16	6.33	6.38
15	15.000	2.6180	47.124	4.50	4.55	4.72	4.99	5.33	5.68	6.01	6.28	6.46	6.51
16	16.000	2.7925	50.265	4.50	4.55	4.73	5.03	5.38	5.76	6.11	6.40	6.59	6.65
18	18.000	3.1416	56.548	4.50	4.55	4.76	5.09	5.49	5.91	6.31	6.63	6.85	6.92
20	20.000	3.4907	62.832	4.50	4.56	4.79	5.16	5.60	6.07	6.51	6.87	7.11	7.19
24	24.000	4.1888	75.398	4.50	4.57	4.84	5.29	5.82	6.39	6.92	7.35	7.64	7.72
30	30.000	5.2360	94.248	4.50	4.59	4.93	5.49	6.15	6.86	7.52	8.06	8.42	8 53
36	36.000	6.2833	113.100	4.50	4.60	5.01	5.68	6.48	7.33	8.13	8.77	9.21	9.33

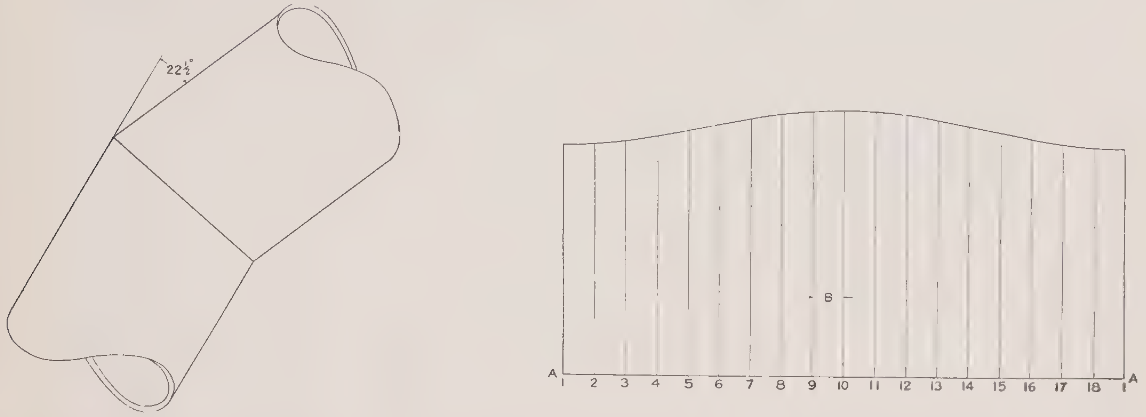
Testing of Welds

Welded pipe lines should be tested in sections as may be convenient, either with water or with air. The water, of course, must not be used unless it can be drained out of the pipe. Air on the other hand should not be used if there is any possibility of breakage of the pipe caused by the test, because an air test always involves more hazard than a water test. The reason for this is the fact that water does not compress and, therefore, if a pipe is ruptured under test, the water does not expand and cause pieces of the broken pipe, or tank, to fly apart. Air on the other hand will compress and when the pressure is released, the air will expand with such violence that a fractured part might break away and fly from the main part causing serious damage. The American Gas Association recommend that the test pressure be one and one-half times the designed working pressure and that an air test be used where it is safe. When an air test is made all joints should be tested for leaks with soap suds. A pin hole leak will, of course, immediately show a soap bubble and can be marked and afterward sealed with the torch.

Spacing of Pipe

The spacing of the lengths of pipe before they are tack welded is important. A pipe from four to six inches in diameter should be spaced one-eighth of an inch between each length before tacking after the two lengths have been lined up. Eight to ten inch pipe should be spaced from five-thirty-seconds to three-sixteenths of an inch and twelve inch pipe three-sixteenth inches. Twenty inch pipe and pipe larger than twenty inches should have at least one-quarter inch between the lengths. The smaller sized pipe should be tack welded at three points and the ten and twelve inch pipe at four points. The twenty inch pipe, as heretofore stated, is tack welded at eight points.

Table Giving Data For Cutting Pipe to Form a 22½ Degree Single Weld Elbow



Shape Assumed by the Completed Templet and Elbow Produced by It.

Size Pipe Inches	Outside Diam. Inches	Dist. B Inches	Length of Base Line A	Length of Ordinates For Single Weld, 22½ Degree Elbow									
				1	2, 18	3, 17	4, 16	5, 15	6, 14	7, 13	8, 12	9, 11	10
2½	2.875	.5017	9.032	4.50	4.52	4.57	4.65	4.74	4.83	4.94	5.02	5.06	5.08
3	3.500	.6110	10.996	4.50	4.53	4.59	4.68	4.80	4.92	5.03	5.12	5.18	5.20
3½	4.000	.6981	12.566	4.50	4.53	4.59	4.70	4.83	4.97	5.10	5.22	5.27	5.30
4	4.500	.7854	14.137	4.50	4.54	4.62	4.74	4.89	5.04	5.20	5.32	5.40	5.43
4½	5.000	.8727	15.708	4.50	4.54	4.62	4.75	4.92	5.09	5.25	5.39	5.47	5.50
5	5.563	.9709	17.477	4.50	4.55	4.63	4.79	4.97	5.16	5.35	5.50	5.59	5.63
6	6.625	1.1563	20.813	4.50	4.55	4.65	4.84	5.05	5.28	5.50	5.67	5.78	5.82
7	7.625	1.3308	23.955	4.50	4.55	4.68	4.89	5.14	5.40	5.65	5.85	5.99	6.04
8	8.625	1.5053	27.096	4.50	4.55	4.71	4.94	5.22	5.53	5.82	6.05	6.21	6.26
9	9.625	1.6799	30.238	4.50	4.56	4.74	4.98	5.30	5.64	5.95	6.21	6.39	6.45
10	10.750	1.8762	33.772	4.50	4.56	4.75	5.05	5.42	5.79	6.17	6.46	6.66	6.73
11	11.750	2.0508	36.914	4.50	4.58	4.79	5.10	5.49	5.90	6.28	6.60	6.80	6.88
12	12.750	2.2253	40.055	4.50	4.58	4.80	5.14	5.56	6.00	6.42	6.76	7.00	7.06
14	14.000	2.4434	43.982	4.50	4.58	4.82	5.20	5.67	6.17	6.63	7.01	7.26	7.36
15	15.000	2.6180	47.124	4.50	4.58	4.84	5.25	5.75	6.29	6.78	7.19	7.46	7.56
16	16.000	2.7925	50.265	4.50	4.58	4.87	5.30	5.84	6.41	6.93	7.37	7.65	7.77
18	18.000	3.1416	56.548	4.50	4.59	4.91	5.40	6.00	6.65	7.24	7.73	8.05	8.18
20	20.000	3.4907	62.832	4.50	4.60	4.96	5.50	6.17	6.89	7.54	8.09	8.44	8.59
24	24.000	4.1888	75.398	4.50	4.62	5.05	5.70	6.51	7.36	8.15	8.80	9.23	9.40
30	30.000	5.2360	94.248	4.50	4.65	5.19	6.00	7.01	8.08	9.06	9.88	10.41	10.63
36	36.000	6.2833	113.100	4.50	4.68	5.32	6.30	7.51	8.79	9.98	10.95	11.60	11.85

These tack welds should be approximately one inch in length and should not be reinforced.

Grade of Steel Used for Pipe Line

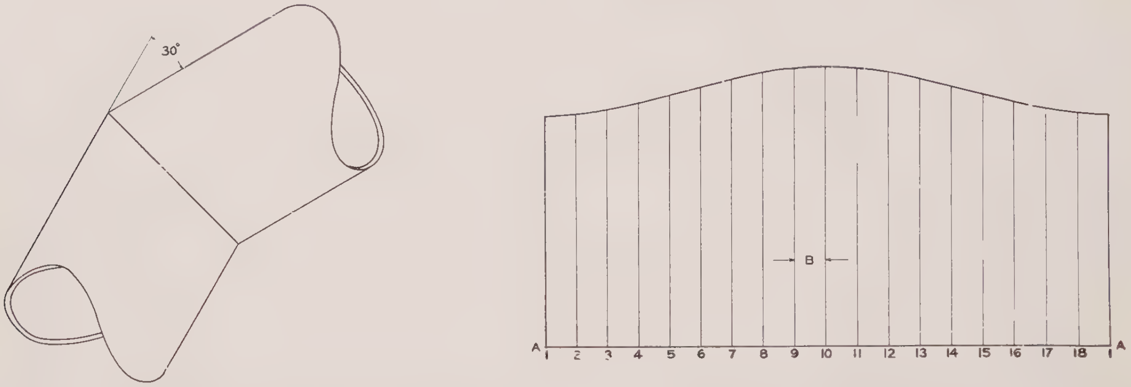
While the grade of steel used in the pipe for pipe lines is not ordinarily a matter for which the welder is responsible, at the same time he should know something about it and also something about the most suitable welding rod for the purpose. The American Gas Association recommend that the pipe material should conform to the A. P. I. standard No. 5-L. This specification can be obtained by writing the association. When such pipe is used welding rod conforming to the American Welding Society specification G-No. 1A, given on page 14, Lesson No. 2, should be used. If a higher grade of steel is used in the pipe than is covered by the above specification, then it is desirable to consider the use of special alloy steel rod for the purpose.

Cutting of Pipe for Welding

Large sized pipe, as considered in this lesson, requires even more careful cutting than the smaller sized pipe, heretofore discussed. It is, therefore, necessary that even more care be taken in using templets than with the smaller pipe. The large templets are too large for publication and for this reason tables are included in this lesson giving the necessary figures to plot the ordinates required. The making of templets was clearly described in Lesson No. 5, and it is only necessary with these tables to lay off the base line, divide the base line into the number of parts given in the tables and lay off the ordinates as given to develop the required curve.

Let us consider, for instance, the making of a templet for cutting eight inch pipe to form a sixty degree single weld elbow. Referring to the table for sixty degree elbows, we find that the length of the base-line for the templet of an eight inch elbow is 27.096 inches. The first operations, therefore, are to obtain a sheet of templet material that is large enough, and to draw a straight line 27.096 inches long. Next the distance between the ordinates, shown in the tables as distance B, should be laid off on the base line starting from the end of the line. In this case the distance is 1.505 inches. After these points have been carefully marked, lines perpendicular to the base line should be erected at each point including the ends of the lines. The perpendicular at each end of the line should be marked number 1, and, starting at the left, the intermediate lines numbered from 2 to 18.

Table Giving Data For Cutting Pipe to Form a 30 Degree Single Weld Elbow



Shape Assumed by the Completed Templet and Elbow Produced by It.

Size Pipe Inches	Outside Diam. Inches	Dist. B Inches	Length of Base Line A	Length of Ordinates For Single Weld, 30 Degree Elbow									
				1	2, 18	3, 17	4, 16	5, 15	6, 14	7, 13	8, 12	9, 11	10
2½	2.875	.5017	9.032	4.50	4.53	4.59	4.71	4.83	4.97	5.09	5.19	5.25	5.28
3	3.500	.6110	10.996	4.50	4.54	4.62	4.75	4.90	5.06	5.21	5.34	5.41	5.44
3½	4.000	.6981	12.566	4.50	4.54	4.63	4.78	4.95	5.14	5.31	5.45	5.54	5.57
4	4.500	.7854	14.137	4.50	4.56	4.65	4.81	5.01	5.22	5.43	5.60	5.70	5.74
4½	5.000	.8727	15.708	4.50	4.56	4.66	4.84	5.06	5.29	5.52	5.69	5.82	5.85
5	5.563	.9709	17.477	4.50	4.56	4.69	4.89	5.13	5.39	5.63	5.84	5.97	6.02
6	6.625	1.1563	20.813	4 50	4.56	4.71	4.96	5.25	5.56	5.85	6.08	6.23	6.29
7	7.625	1.3308	23.955	4.50	4.57	4.73	5.02	5.36	5.72	6.05	6.32	6.50	6.56
8	8.625	1.5053	27.096	4.50	4.57	4.77	5.08	5.47	5.88	6.26	6.58	6.78	6.86
9	9.625	1.6799	30.238	4.50	4.58	4.82	5.15	5.58	6.03	6.46	6.82	7.04	7.13
10	10.750	1.8762	33.772	4.50	4.58	4.84	5.24	5.72	6.24	6.71	7.10	7.36	7.45
11	11.750	2.0508	36.914	4.50	4.60	4.88	5.29	5.81	6.35	6.87	7.29	7.56	7.66
12	12.750	2.2253	40.055	4.50	4.61	4.90	5.34	5.90	6.50	7.04	7.51	7.82	7.90
14	14.000	2.4434	43.982	4.50	4.61	4.94	5.43	6.06	6.73	7.36	7.85	8.18	8.30
15	15.000	2.6180	47.124	4.50	4.62	4.97	5.50	6.17	6.89	7.56	8.09	8.44	8.57
16	16.000	2.7925	50.265	4.50	4.63	5.00	5.56	6.28	7.05	7.77	8.33	8.71	8.84
18	18.000	3.1416	56.548	4.50	4.64	5.07	5.70	6.51	7.37	8.18	8.81	9.23	9.39
20	20.000	3.4907	62.832	4.50	4.66	5.13	5.83	6.73	7.69	8.59	9.29	9.76	9.94
24	24.000	4.1888	75.398	4.50	4.69	5.25	6.09	7.17	8.32	9.40	10.24	10.81	11.03
30	30.000	5.2360	94.248	4.50	4.74	5.44	6.49	7.84	9.28	10.63	11.68	12.39	12.66
36	36.000	6.2833	113.100	4.50	4.78	5.63	6.89	8.51	10.23	11.85	13.11	13.96	14.30

Figures in the ten columns at the right of the table show the lengths of the ordinates measured from the base line. It will be noted that each column except the first and last have two numbers at the top of the column. This is because as explained in Lesson No. 5, the ordinates are directly opposite each other on the pipe and have the same length. The next step is to mark on the perpendicular lines, or ordinates, the lengths shown in the tables for eight inch pipe. The length of line number 1, shown as 4.50 inches, should be accurately marked on the perpendicular at each end of the line; then lengths numbered 2 and 18, shown as 4.66 inches should be measured on the ordinates numbered 2 and 18. This should be continued until all of the ordinates are properly marked. The final step in laying out the templet is to draw a smooth curve through all of the marked points of the ordinates. This should be very carefully done with the aid of a draftman's curve or other similar instrument. After this has been done the templet may be cut out and used in the manner described in previous lessons.

Clamps for Welding Pipe

There are a great many clamps which have been devised after practical field experience which assist to a very large extent in lining and handling the pipe prior to tack welding. An excellent clamp which was used to align a twelve inch steam pipe is shown in Figure 10. This consisted of four pieces of one and one-half by three-eighths inch strap iron welded to two strap iron clamps two inches in width and one-half inch in thickness. The clamps were held by five-eighths inch bolts and clamped tight to the pipe. The ends of the two sections of pipe were placed in approximate alignment and this clamp placed in position. The pipe had been bevelled at the mill before shipment was made and, therefore, no bevelling was necessary. It was separated three-sixteenths of an inch and the bolts pulled up tight. This held the pipe in alignment while it was being tack welded in four places. Figure 11 shows a clamp used to draw the ends of two pieces of eight inch steam pipe together.

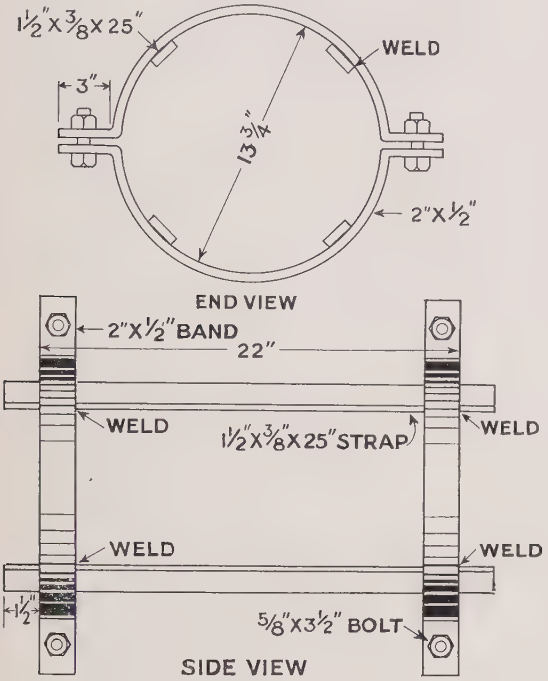


Figure 10—Sketch Showing a Clamp Used to Align Steam Pipe. The Clamp was Placed Over the Ends of the Pipe Adjacent the Joint to be Welded and the Bolts Pulled Up Tight. This Clamp Held the Pipe in Alignment While It was Being Tack Welded.

Some of the pipe was too far apart and there was no way to draw the lengths together as they rested upon the hangers which held them at the right distance while tack welding was being done. The jig shown in Figure 11 served this purpose in a satisfactory manner. The two inch steel bands were clamped around the ends of the two lengths of pipe, the rods placed through the clamps and the two pipes drawn together by screwing up on the nuts. Figure 12 shows another type of clamp used to keep the pipe in line. This clamp is made of a pair of sprocket chains. At the same time it can be used to draw the two lengths of pipe together and is, therefore, a combination of the clamp shown in Figures 10 and 11.

In Figure 13 another type of clamp is shown which is made of bars, handle screws and pieces of scrap iron. It is a little more complicated to construct, but has the advantage that it can be easily and quickly removed from the pipe line. All of these clamps with the exception of the chain clamp are home-made affairs and have been developed on various jobs where work of this kind has been carried on. Figure 14 shows a roller support which can be easily made up from scrap plate. Two wheels are cut with the cutting torch from fairly heavy plate, while a tramel bar attached to the torch is used to make a perfect circle. The wheels are drilled at the center and the box like structure can be made solid as shown in Figure 14, or can be made up of welded frame work, whichever may be convenient. Two bolts serve as axles and four holes may be drilled in the base and the roller support mounted on a timber, if desired.

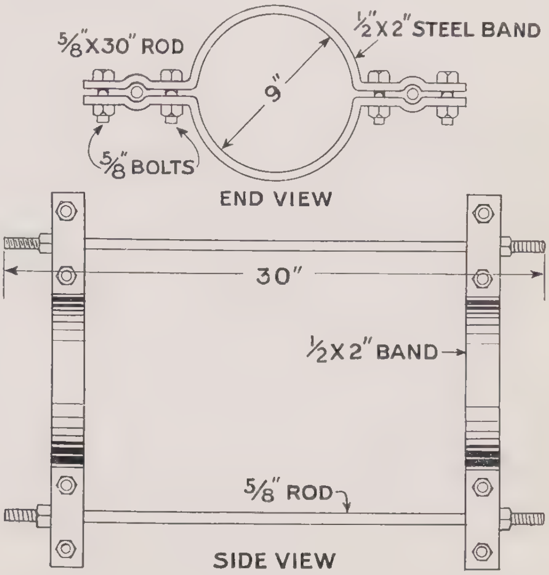


Figure 11—Clamp Used Upon an Eight Inch Steam Pipe to Pull the Ends of the Pipe Together When They Were too Far Apart. The Pipe Rested Upon Hangers in a Tunnel and the Clamps Were Clamped Over the Ends of the Pipe, the Rods Placed Through the Opening And the Pipe Lengths Pulled Together by Screwing Up the Nuts.

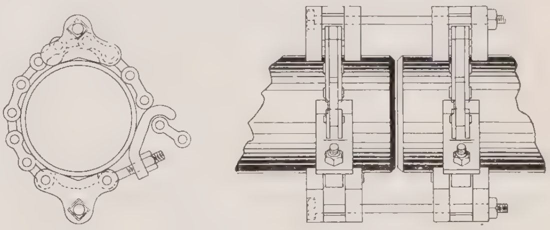


Figure 12—This is a Chain Clamp Utilizing Two Sprocket Chains, Two Special Castings and Some Bolts to Make a Combination Clamp for Keeping the Pipe in Alignment and for Drawing It Up Together if Necessary.

Another type of pipe roller support is shown in Figure 15. This consists of two rollers which can be procured commercially, or made up of pieces of plate and circular pieces of steel cut with the torch, all mounted upon a wood base. Such rollers are a great convenience and materially assist in making uniform welds. Figure 16 illustrates a very simple type of clamp to keep pipe in alignment, made of a piece of angle iron to which two C clamps of the standard variety have been welded. This is a very simple clamp and serves its purpose well.

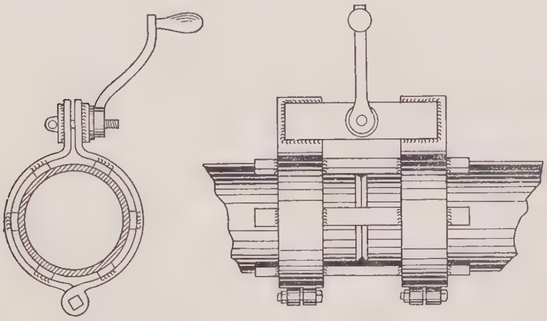


Figure 13—This is Still Another Type of Home Made Clamp With a Handle to Screw It Tight So That It may be Quickly Put on the Pipe and Removed.

Welded Steam Pipe in Buildings

One of the newer fields for welded steam pipe is in large buildings and many illustrations could be shown of welded pipe lines in buildings, not only for steam, but for refrigeration and other piping systems. One or two of these will suffice to show the result of welding in building construction. These have been made as large as possible to show the detail and were taken in a modern office building forty-two stories in height, recently constructed in Chicago. Figure 17 shows a view of the steam piping supported from the floor system where two lines of pipe make a ninety degree turn. This is particularly interesting, because of the branches from these pipes and the two methods for making this turn. The upper line utilizes a tube turn AB.

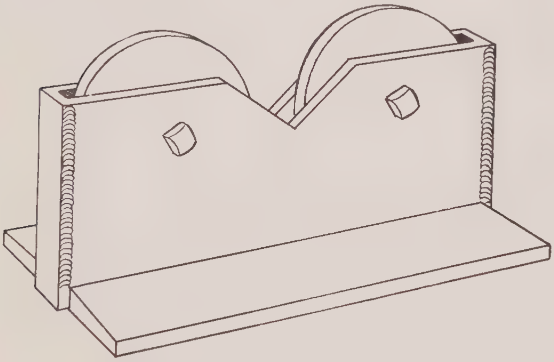


Figure 14—Sketch Showing a Roller Base for Supporting Pipe so That the Lengths Can Be Turned Easily. These Can be Made Out of Scrap Material and Can Be Welded by the Welding Crew in Bad Weather.

A tube turn is a bend in pipe made by special machinery to produce an elbow, or bend having the same thickness of wall throughout. Such a tube turn has been welded to the straight sections of pipe lines at A and B. In the lower pipe line C two forty-five degree elbows have been cut in pipe and welded, making a two piece ninety degree turn. At D a reduction in the size of the pipe line to a smaller line is shown. It should be noted that this reduction is made so that the lower portion of the pipe is smooth and level and the reduction in size is accomplished around the upper circumference of the pipe. In this manner a reducer can be made which will not interfere with the flow of water in the pipe.

In Figure 18 this same pipe construction or bend is shown and all of the welds in the foreground have been marked with arrows. There are a number of welds in the background, but these are not sufficiently distinct to be readily seen. This picture gives a clear idea of the extent of the system. It should be remembered that these photographs illustrate welded piping on but one floor. There were forty-two floors in this building and while the piping, of course, was not so extensive on each floor, the number of welded joints in a building of this kind is enormous. There are other interesting details in both Figures 17 and 18, one of which is the manner in which the nipple is taken off from the lower part of the large pipe line in Figure 17 to provide a connection to the special valve shown in the upper right hand corner of the picture.

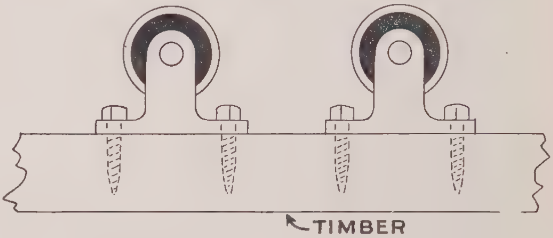


Figure 15—Sketch Showing a Pipe Rolling Support Made with Two Rollers, Mounted Upon a Timber.

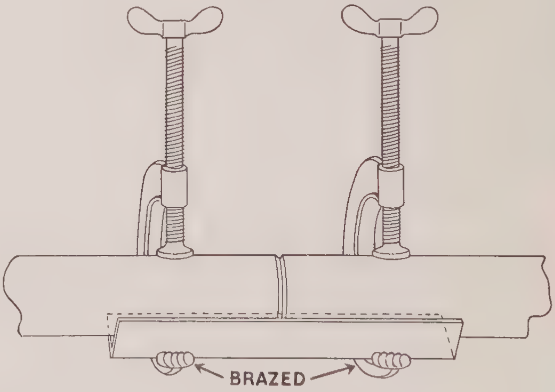


Figure 16—An Alignment Pipe Clamp Made of a Piece of Angle Iron with Two C Clamps of the Ordinary Welding Shop Type Welded to It.

Steam piping in buildings offers an enormous field for the welding process which the steam fitting trade has already recognized and steam fitters throughout the country are taking up welding on a very considerable scale. The welding of piping in buildings, of course, presents some entirely different problems from those encountered in either the welding of oil or gas transmission lines. The actual welding of the pipe is essentially the same, but in many instances the ingenuity and dexterity of the operator are heavily taxed to enable him to do the work as it should be done in the confined spaces. Expansion and contraction are taken care of by angular bends as illustrated in the photograph and by special expansion bends at points in the line, where the lengths of straight pipe become so great that linear expansion and contraction must be compensated for.

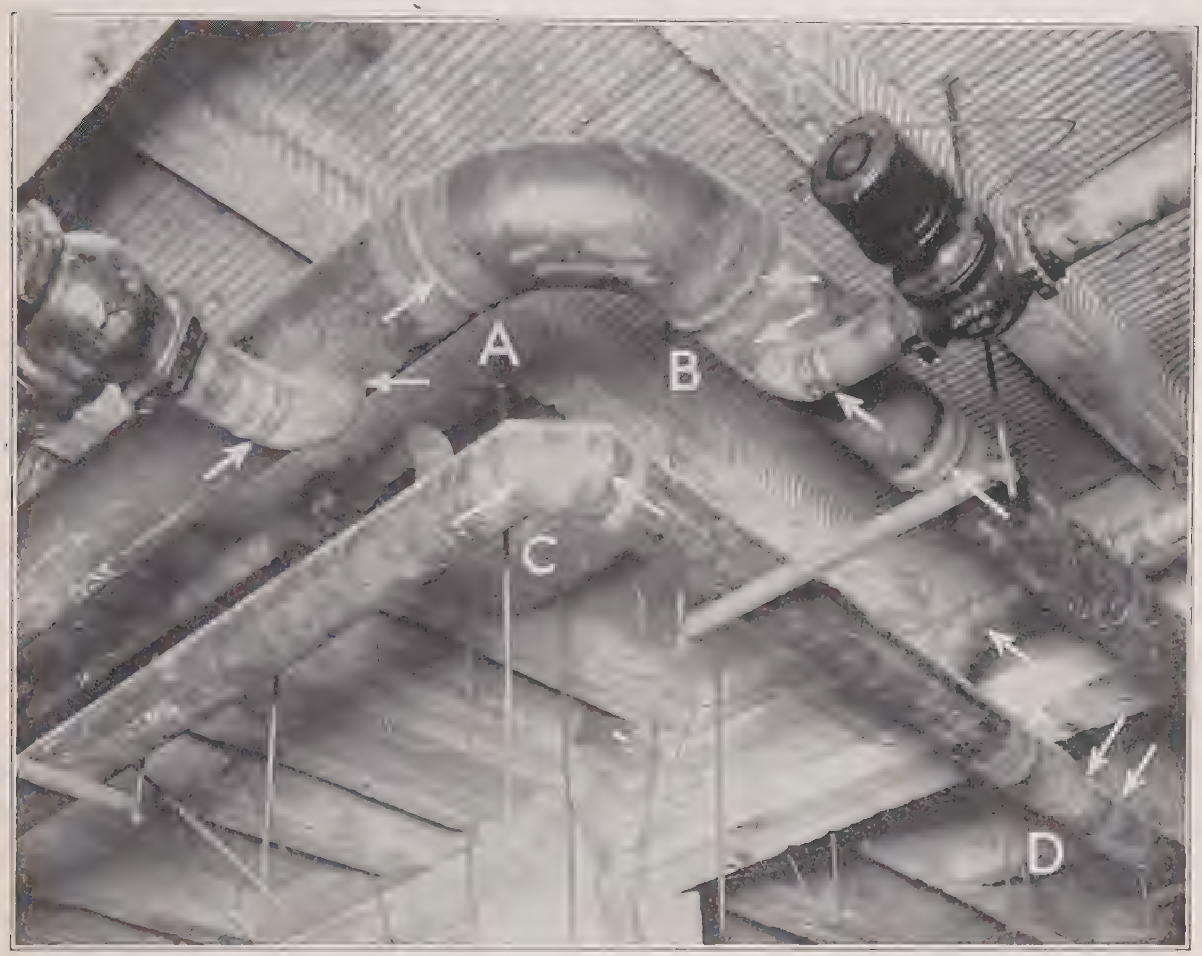


Figure 17—View of Welded Pipe Bends in a Large Office Building. The Upper Bend is Made with a Tube Turn and the Lower Bend with Two Forty-Five Degree Welded Joints.

Welded Oil Conveying Pipe Lines

This field is tremendous in extent and there are at the present time many oil lines extending across the country from the oil fields to eastern refineries and from field to refinery in the oil country. Few men realize the extent of these lines and the fact that transportation of oil in this manner enables the manufacture of its products at a price which would not be possible if all oil were transported upon the railroads in tank cars. The pressure in these lines is quite high and welding upon all new lines and extensions is standard practice.

The report of the Oxy-Acetylene Committee of the International Acetylene Association for 1928 states that one welded pipe line 1,330 miles in length has been constructed and also another line 530 miles long. Another has recently been laid 300 miles in length and others, including eight or ten major projects all over 200 miles in length. These were all eight and ten inches in diameter. In the larger lines several hundred miles of 16, 18 and 20 inch diameter pipe were welded in 1928.

Welded Natural Gas Conveying Pipe Lines

In the natural gas fields, there is, of course, an enormous opportunity for the construction of welded pipe lines for conveying natural gas under high pressure from the gas fields to cities and other points where it is consumed. The great advantage of the welded joint, of course, is the fact that it is gas tight and that leakage is reduced to a minimum.

Welded High Pressure Gas Lines for City Gas

For a good many years cities have been supplied with illuminating gas. This gas has been generated at central stations and delivered into large gasometers where the gas has been stored at a pressure of a few ounces. Pipe lines from these gasometers distributed the gas throughout the city limits under low pressure. As the suburbs surrounding the cities became more populous a very considerable demand arose for city gas or illuminating gas in these suburbs. The size of the pipe for conveying gas under low pressure was so great that it was found economic to increase the pressure within the gas mains leading to suburban communities to fifty or sixty pounds per square inch and under these conditions the older types of joints proved inadequate. For this reason the high pressure gas lines conveying gas to the consumer in the suburban towns are today much smaller all-welded gas lines. In this field welded joints are standard practice for all new high pressure gas lines and new extensions from old lines.

Welding Steam Piping in City Streets

In some cities there are central steam plants supplying steam in the down town districts to office and store buildings. This system requires the laying of steam mains in the city streets from the central plant to the buildings heated by it. These steam lines are usually laid in concrete conduits just big enough to contain the line and the roller supports upon which the pipe rests. At points along the line man-holes are constructed and at each man-hole there is usually a special slip joint in the pipe line to take care of expansion and contraction. All of the joints, however, between the expansion joints are welded. More recently one of the large universities in a city built a steam plant on one side of a long, wide parkway. It was necessary to convey the steam to the various university buildings located across the parkway and at a considerable distance along the parkway from the central steam plant. In this instance there was plenty of room and no restriction to the manner in which the steam pipes could be

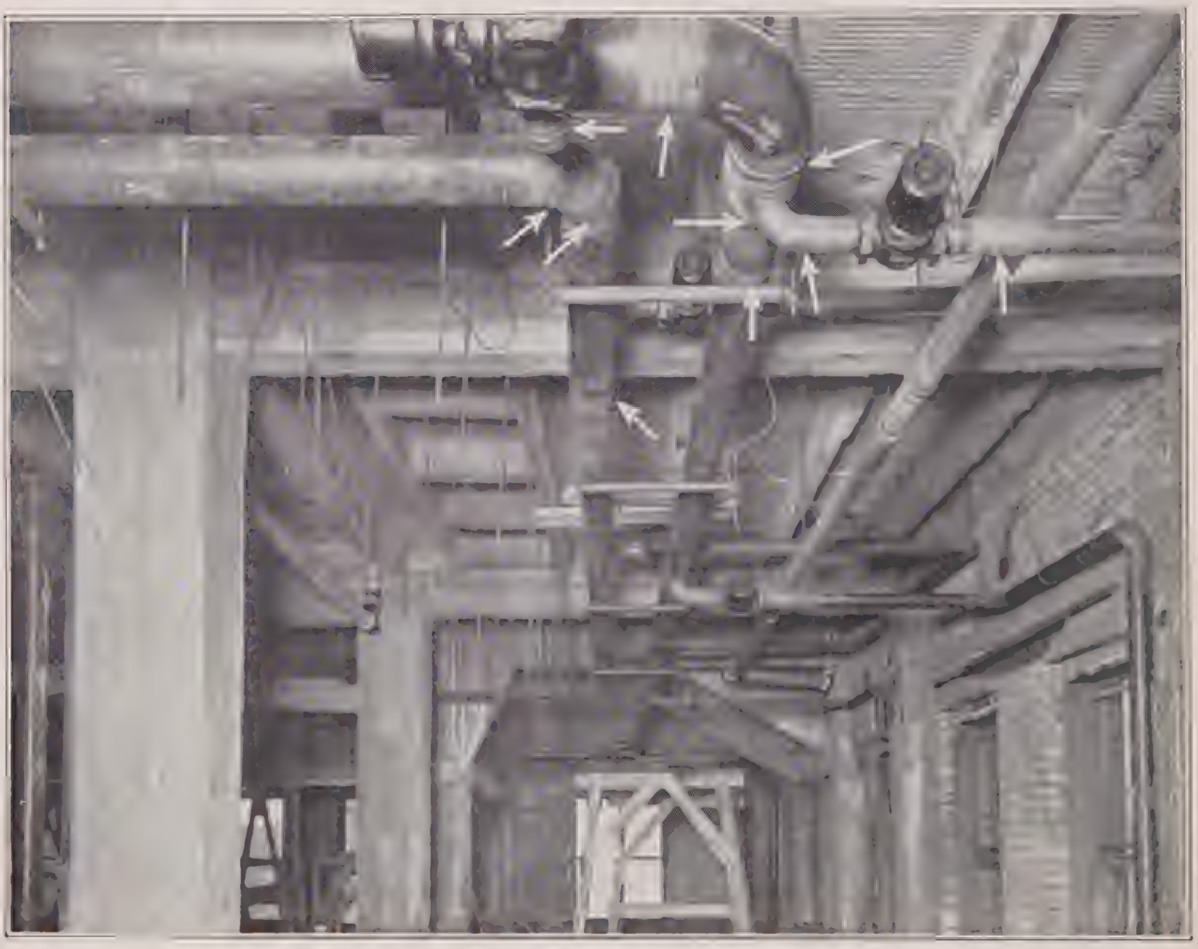
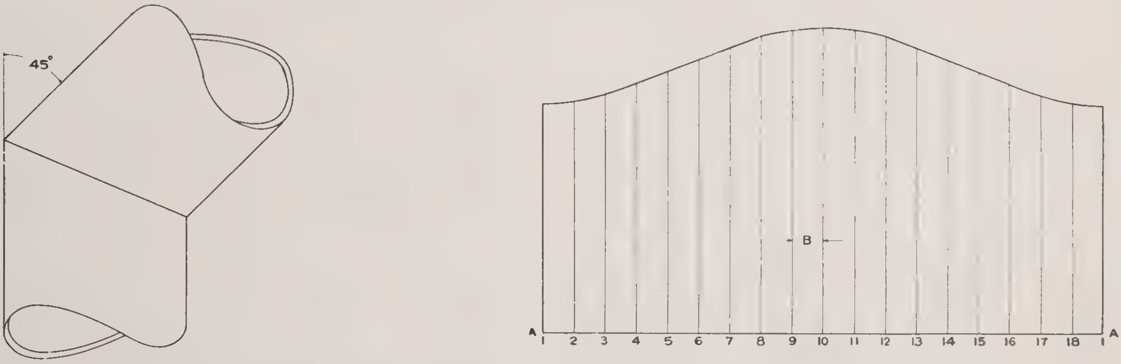


Figure 18—A View Showing the Welded Steam Piping on One Floor. This is but a Very Small Portion of the Welded Steam Piping on Every Floor of this New Forty-two Story Building.

laid. Therefore a tunnel was built about eight feet high and eight feet wide, entirely of concrete, and just below the surface of the ground.

Every three or four hundred feet a U shaped off-set was made in the tunnel to allow for a similar U bend in the pipe line. The U bend, of course, has the advantage in compensating for expansion and contraction that there is no possibility of leakage at the joints. Every joint is a welded joint and expansion and contraction of the pipe is entirely taken care of by the bending of the U. This method of off-setting a tunnel to accommodate a U bend is quite novel, and, of course, could be accomplished only where the pipe line was not confined to a limited area.

Table Giving Data For Cutting Pipe to Form a 45 Degree Single Weld Elbow



Shape Assumed by the Completed Templet and Elbow Produced by It.

Size Pipe Inches	Outside Diam. Inches	Dist. B Inches	Length of Base Line A	Length of Ordinates For Single Weld, 45 Degree Elbow									
				1	2, 18	3, 17	4, 16	5, 15	6, 14	7, 13	8, 12	9, 11	10
2½	2.875	.5017	9.032	4.50	4.54	4.60	4.80	5.01	5.21	5.40	5.56	5.65	5.70
3	3.500	.6110	10.996	4.50	4.55	4.68	4.88	5.11	5.37	5.60	5.80	5.92	5.96
3½	4.000	.6981	12.566	4.50	4.56	4.69	4.92	5.18	5.47	5.73	5.96	6.10	6.14
4	4.500	.7854	14.137	4.50	4.57	4.73	4.97	5.29	5.61	5.92	6.16	6.35	6.40
4½	5.000	.8727	15.708	4.50	4.57	4.75	5.02	5.36	5.72	6.04	6.32	6.52	6.58
5	5.563	.9709	17.477	4.50	4.58	4.77	5.09	5.47	5.87	6.25	6.56	6.77	6.85
6	6.625	1.1563	20.813	4.50	4.59	4.81	5.20	5.64	6.12	6.56	6.92	7.15	7.23
7	7.625	1.3308	23.955	4.50	4.60	4.87	5.30	5.81	6.36	6.89	7.32	7.61	7.71
8	8.625	1.5053	27.096	4.50	4.61	4.93	5.40	5.99	6.62	7.21	7.69	8.00	8.09
9	9.625	1.6799	30.238	4.50	4.63	4.99	5.50	6.17	6.88	7.53	8.05	8.43	8.55
10	10.750	1.8762	33.772	4.50	4.64	5.03	5.64	6.37	7.16	7.90	8.51	8.90	9.04
11	11.750	2.0508	36.914	4.50	4.65	5.08	5.74	6.54	7.36	8.16	8.80	9.23	9.38
12	12.750	2.2253	40.055	4.50	4.66	5.12	5.82	6.68	7.60	8.50	9.17	9.68	9.84
14	14.000	2.4434	43.982	4.50	4.67	5.18	5.97	6.94	7.96	8.94	9.72	10.23	10.42
15	15.000	2.6180	47.124	4.50	4.68	5.23	6.08	7.11	8.21	9.26	10.09	10.64	10.84
16	16.000	2.7925	50.265	4.50	4.69	5.28	6.18	7.29	8.45	9.57	10.47	11.05	11.27
18	18.000	3.1416	56.548	4.50	4.72	5.37	6.39	7.64	8.95	10.21	11.21	11.87	12.11
20	20.000	3.4907	62.832	4.50	4.74	5.47	6.60	7.99	8.44	10.84	11.96	12.69	12.96
24	24.000	4.1888	75.398	4.50	4.79	5.79	7.02	8.68	10.43	12.11	13.45	14.32	14.65
30	30.000	5.2360	94.248	4.50	4.86	5.96	7.65	9.73	11.91	14.01	15.69	16.78	17.19
36	36.000	6.2833	113.100	4.50	4.94	6.25	8.28	10.77	13.40	15.92	17.92	19.23	19.72

Welded Overhead Steam Piping in Manufacturing Plants and Mining Properties

This field also presents tremendous possibilities for welded pipe lines. Often a central steam heating plant will be located upon a property of considerable extent and it becomes necessary to convey the steam through overhead lines supported from structural steel towers or along the sides of buildings to the points of consumption. In such instances there is usually no restriction in the area occupied and for this reason U bends are quite common. The welded pipe, of course, has the very great advantage that it can be covered with asbestos covering without interference at the joints.

Welded Power Plant Piping

Welded pipe lines in power plants consist more largely in the welding of large diameter pipe and headers. Where several pipe lines from boilers are to be manifolded into one large line, headers are necessary providing branches from the main line for the various supply and discharge lines from the boilers. The welding of these headers offers a tremendous field for the welder to show his skill in compensating for contraction and expansion. For instance with a long header welding is accomplished on each branch from the main pipe, often all on one side of this pipe. The problem then is to do this work without warping the main pipe out of alignment.

When welding nipples in a larger pipe constituting a header or manifold, or in pipes of equal diameter, care must be taken to apply the heat in the right manner in order to compensate for the expansion and contraction which must take place. When several welds are to be made on one side of a pipe, that side of the pipe will contract or shorten causing the pipe to bend downward. This is the result of the expansion of the hot metal and its upsetting because the colder metal surrounding it confines it and prevents the hot section from expanding freely. The metal must go somewhere, therefore, it upsets slightly and when it cools that side of the pipe is shorter.

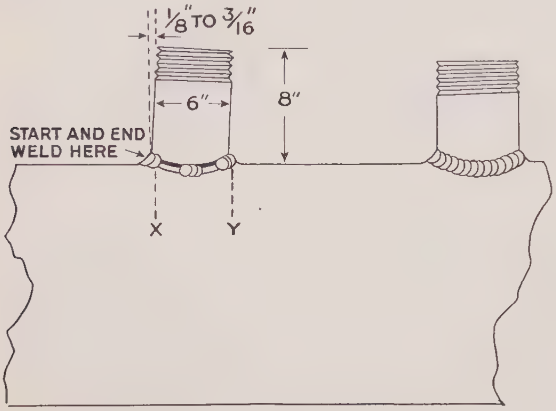


Figure 19—Sketch Showing a Nipple Welded into a Larger Pipe. By Tack Welding the Nipple in Place Slightly Out of Square and Starting and Ending the Weld at X, as Shown, the Nipple Will Draw Over Toward the Point X into Correct Alignment. This is Because the Circumference at X has Been Heated Twice and Will Contract More than the Circumference at Y, Which has been Heated Only Once.

If only one nipple were to be welded in the side of the pipe, the effect would be comparatively slight and probably would not be noticed, but if eight or ten nipples are to be welded in the side of a pipe, perhaps eighteen or twenty feet long, the upsetting of the heated metal and the subsequent contraction will cause the pipe to sag several inches. The pipe may be straightened by heating it upon the opposite side of each nipple, applying approximately the same amount of heat as was used to weld the nipple in place. Normally, such treatment should bring the pipe back to alignment. Heat can also be applied on the opposite side of the pipe between the nipples and the pipe straightened by mechanical force.

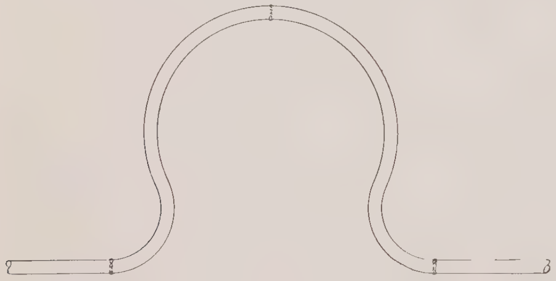


Figure 20—U Bend in Pipe Used to Take Care of Linear Expansion and Contraction Particularly in Steam Pipe Lines.

It is necessary in welding nipples in pipe to be sure that they are square with the surface of the pipe. A six inch nipple eight inches long will, when welded to a pipe sixteen or eighteen inches in diameter, warp out of square from one-eighth to three-sixteenth inches. This warping can be compensated for, as shown in Figure 19, by tack welding the nipples into position from one-eighth to three-sixteenth inches out of square and starting the weld at the point X and welding clear around the nipple so that the weld will end also at the point X, as shown in Figure 19. When this is done the circumference at X has been heated twice and the circumference at Y but once, therefore, the circumference at X will contract more than at Y and cause the nipple to draw over square.

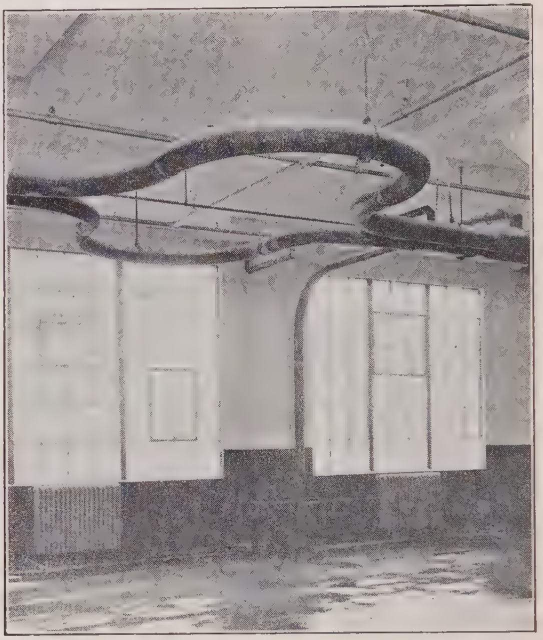


Figure 21—This Photograph Shows Two Typical Welded Expansion Bends. The Pipe in the Foreground is Eight Inches in Diameter, While that in the Background is Four Inches in Diameter. To Make these Expansion Bends Two 180 Degree Pipe Bends of Each Diameter were Purchased, One of Each of These Cut in Half and a Ninety Degree Section Welded to Each End of the Remaining 180 Degree Section.

Where six or eight three inch nipples, for instance, are to be welded into a ten inch pipe twelve or fourteen feet in length, a simple manner of compensating for the effect of welding these nipples into the side of the pipe is to bend a piece of pipe an inch or more out of line, depending upon the length of the pipe, and the number of nipples to be welded into place, which can be determined by experiment. The nipples would then be welded to the long side of the pipe and as the heat and subsequent contraction will tend to upset the metal and shorten this side of the pipe, the contraction will pull the pipe straight.

These examples should enable the student to partially visualize the many uses to which welding may be applied in the pipe line field.

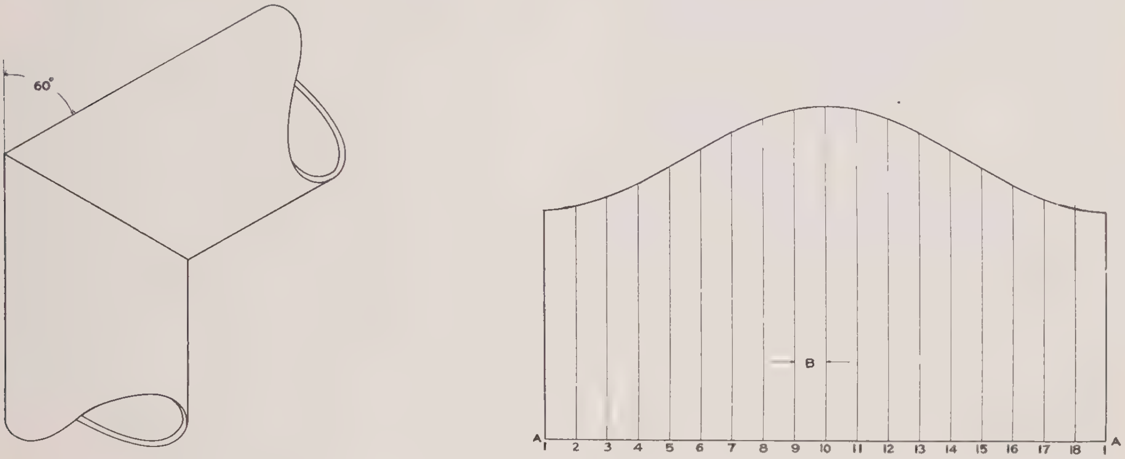
Job Sheet No. 6

Butt Welding Six Inch Pipe

With the description which has been given in this lesson of the various methods for welding large pipe, the student should now be able to select the proper equipment and plan and execute the work required upon this job sheet without detailed directions which have been given in job sheets heretofore. For this reason detailed directions will not be given, but the student will be expected to carry out the work in accordance with the practice which has been taught so far.

1. The first job required will be the butt welding of two pieces of six inch pipe, each six inches long. The pipe may be turned while making this weld. The method of preparation, the equipment to be used, the size of the welding rod and the manner of procedure will be left entirely to the student.
2. The second job will be the butt welding of two pieces of six inch pipe each six inches long, but in a stationary position about four feet above the floor. This can be accomplished by making two convenient supports of two pieces of horizontal angle iron welded to two short pieces of one-half inch pipe which may be attached to the welding table.
3. From each of these finished welds, cut sample pieces one and one-half inches wide and approximately eight inches long, so that one of these includes a junction point at the start and the finish of the weld. Place these pieces in a vise, as described in the text, and break the weld. Carefully examine the weld for defects and write a report upon the result.

Table Giving Data For Cutting Pipe to Form a 60 Degree Single Weld Elbow



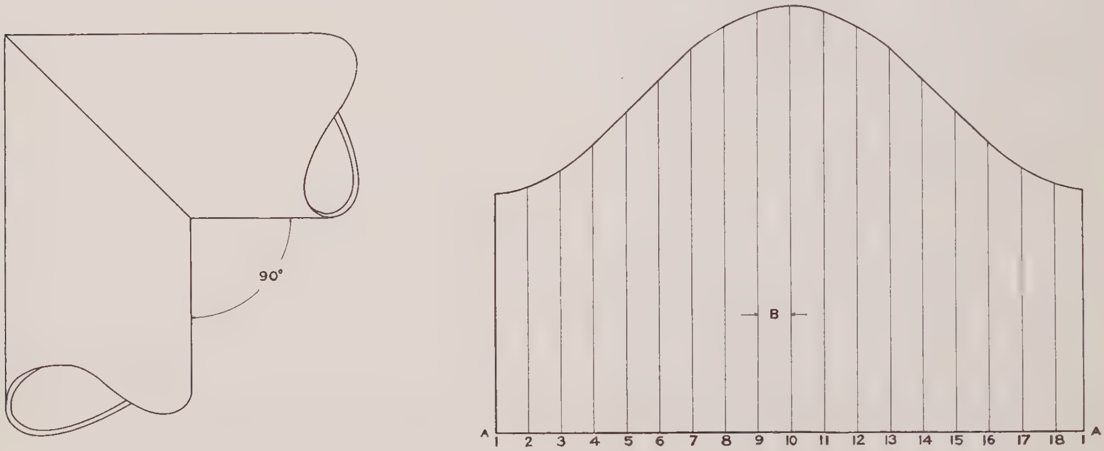
Shape Assumed by the Completed Templet and Elbow Produced by It.

Size Pipe Inches	Outside Diam. Inches	Dist. B Inches	Length of Base Line A	Length of Ordinates For Single Weld, 60 Degree Elbow									
				1	2, 18	3, 17	4, 16	5, 15	6, 14	7, 13	8, 12	9, 11	10
2½	2.875	.5017	9.032	4.50	4.56	4.70	4.93	5.19	5.48	5.74	5.97	6.11	6.16
3	3.500	.6110	10.996	4.50	4.57	4.75	5.02	5.35	5.70	6.03	6.30	6.47	6.52
3½	4.000	.6981	12.566	4.50	4.58	4.77	5.08	5.46	5.87	6.23	6.53	6.73	6.80
4	4.500	.7854	14.137	4.50	4.59	4.80	5.15	5.57	6.02	6.45	6.81	7.03	7.11
4½	5.000	.8727	15.708	4.50	4.60	4.81	5.23	5.70	6.20	6.68	7.07	7.33	7.42
5	5.563	.9709	17.477	4.50	4.61	4.88	5.32	5.83	6.39	6.92	7.35	7.64	7.74
6	6.625	1.1563	20.813	4.50	4.62	4.92	5.42	6.01	6.64	7.22	7.70	8.02	8.12
7	7.625	1.3308	23.955	4.50	4.64	5.01	5.62	6.34	7.09	7.82	8.42	8.82	8.97
8	8.625	1.5053	27.096	4.50	4.66	5.11	5.76	6.59	7.45	8.26	8.93	9.39	9.55
9	9.625	1.6799	30.238	4.50	4.68	5.16	5.88	6.79	7.78	8.67	9.40	9.90	10.08
10	10.750	1.8762	33.772	4.50	4.69	5.23	6.06	7.09	8.15	9.17	10.02	10.56	10.75
11	11.750	2.0508	36.914	4.50	4.71	5.31	6.21	7.37	8.42	9.58	10.48	11.19	11.30
12	12.750	2.2253	40.055	4.50	4.74	5.37	6.34	7.53	8.80	10.03	11.00	11.66	11.88
14	14.000	2.4434	43.982	4.50	4.75	5.44	6.52	7.87	9.28	10.61	11.68	12.38	12.66
15	15.000	2.6180	47.124	4.50	4.76	5.51	6.66	8.11	9.62	11.05	12.19	12.94	13.24
16	16.000	2.7925	50.265	4.50	4.77	5.57	6.81	8.35	9.96	11.48	12.71	13.51	13.83
18	18.000	3.1416	56.548	4.50	4.81	5.71	7.10	8.83	10.65	12.36	13.73	14.63	14.99
20	20.000	3.4907	62.832	4.50	4.84	5.84	7.39	9.31	11.33	13.23	14.76	15.76	16.16
24	24.000	4.1888	75.398	4.50	4.91	6.11	7.96	10.28	12.69	14.97	16.81	18.01	18.49
30	30.000	5.2360	94.248	4.50	5.01	6.51	8.83	11.72	14.74	17.59	19.89	21.39	21.99
36	36.000	6.2833	113.100	4.50	5.12	6.92	9.69	13.17	16.79	20.21	22.96	24.76	25.48

Questions:

1. Are steel, iron and cast iron elastic?
2. What causes expansion and contraction of metal?
3. When welding two sheets of steel together, how is expansion taken care of?
4. Is the method of tack welding large pipe different from that used in previous lessons?
5. What is the reason for the difference?
6. Describe three methods of welding lengths of pipe together when building a large diameter pipe line?
7. A steel pipe line, free at both ends, on a day when the temperature is 105 degrees above zero measures exactly 1,843 feet long. What is its length when the temperature is thirty degrees above zero?
8. Describe two means used to compensate for expansion and contraction in large pipe.
9. What causes a pipe header to warp after a number of nipples have been welded to it?
10. How is this warpage eliminated?

Table Giving Data For Cutting Pipe to Form a 90 Degree Single Weld Elbow



Shape Assumed by the Completed Templet and Elbow Produced by It.

Size Pipe Inches	Outside Diam. Inches	Dist. B Inches	Length of Base Line A	Length of Ordinates For Single Weld, 90 Degree Elbow									
				1	2, 18	3, 17	4, 16	5, 15	6, 14	7, 13	8, 12	9, 11	10
2½	2.875	.5017	9.032	4.50	4.60	4.85	5.23	5.70	6.19	6.66	7.05	7.28	7.37
3	3.500	.6110	10.996	4.50	4.62	4.92	5.40	5.96	6.57	7.14	7.60	7.88	8.00
3½	4.000	.6981	12.566	4.50	4.64	4.97	5.52	6.18	6.89	7.53	8.06	8.39	8.50
4	4.500	.7854	14.137	4.50	4.65	5.03	5.63	6.34	7.13	7.86	8.47	8.88	9.00
4½	5.000	.8727	15.708	4.50	4.66	5.11	5.76	6.56	7.45	8.27	8.92	9.36	9.50
5	5.563	.9709	17.477	4.50	4.67	5.15	5.90	6.79	7.77	8.69	9.44	9.67	10.13
6	6.625	1.1563	20.813	4.50	4.71	5.26	6.19	7.25	8.41	9.49	10.36	10.94	11.13
7	7.625	1.3308	23.955	4.50	4.73	5.39	6.42	7.66	8.98	10.23	11.27	11.94	12.13
8	8.625	1.5053	27.096	4.50	4.78	5.54	6.69	8.11	9.58	10.97	12.15	12.91	13.13
9	9.625	1.6799	30.238	4.50	4.79	5.65	5.92	8.45	10.11	11.69	12.97	13.82	14.13
10	10.750	1.8762	33.772	4.50	4.82	5.75	7.20	8.94	10.79	12.55	14.00	14.90	15.25
11	11.750	2.0508	36.914	4.50	4.87	5.89	7.45	9.37	11.39	13.29	14.89	15.93	16.32
12	12.750	2.2253	40.055	4.50	4.88	5.96	7.86	9.74	11.97	14.04	15.76	16.88	17.25
14	14.000	2.4434	43.982	4.50	4.94	6.15	8.03	10.32	12.72	15.02	16.85	18.07	18.50
15	15.000	2.6180	47.124	4.50	4.97	6.27	8.28	10.74	13.31	15.77	17.73	19.04	19.50
16	16.000	2.7925	50.265	4.50	5.00	6.39	8.53	11.15	13.89	16.52	18.61	20.01	20.50
18	18.000	3.1416	56.548	4.50	5.07	6.62	9.04	11.98	15.07	18.03	20.38	21.95	22.50
20	20.000	3.4907	62.832	4.50	5.13	6.86	9.54	12.81	16.24	19.53	22.14	23.89	24.50
24	24.000	4.1888	75.398	4.50	5.25	7.33	10.62	14.48	18.59	22.53	25.67	27.76	28.50
30	30.000	5.2360	94.248	4.50	5.44	8.04	12.06	16.97	22.11	27.04	30.96	33.58	34.50
36	36.000	6.2833	113.100	4.50	5.63	8.74	13.58	19.47	25.64	31.55	36.26	39.39	40.50

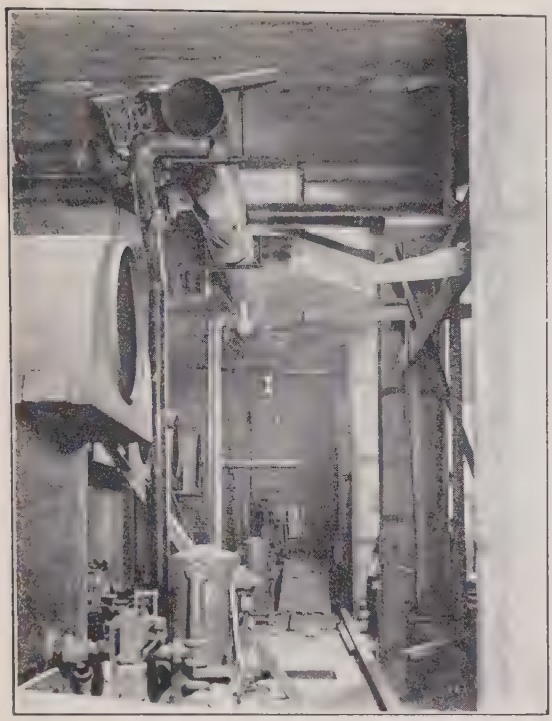


Figure 22—A Photograph Showing how Five High Pressure Boilers Were Connected to a Twenty Inch Header Approximately Fifty Feet Long. The Joints in This Header were Oxy-Acetylene Welded.

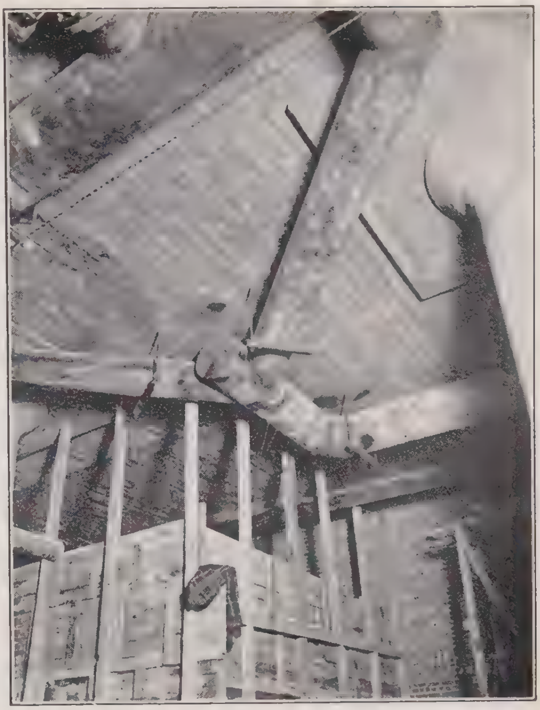


Figure 24—This Illustration Shows how Two Twelve Inch Branches from the Header were Connected into a Twenty Inch Main Line Which Runs up to the Top of the Building, Supplying a Down-Feed Heating System.

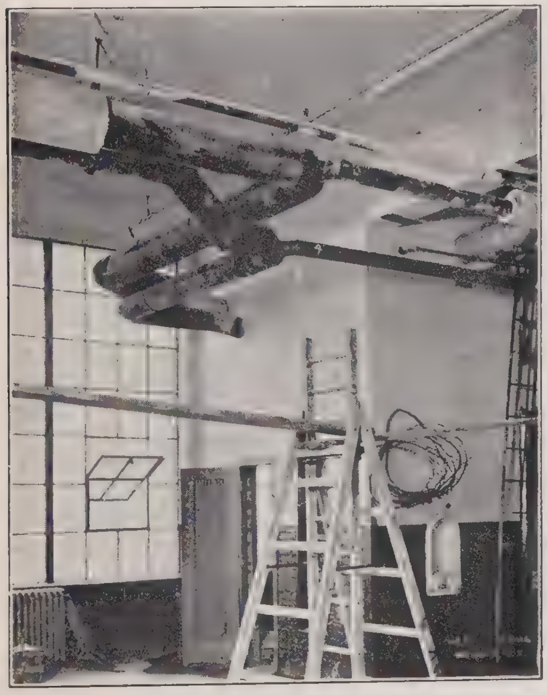


Figure 23—A View of the Seventh Story of the Building, Showing Various Reducers, Elbows and Branches. When This Line was being Tested with High Pressure Steam, Defective Concrete Permitted the Pipe Hangers to Pull Out of the Ceiling and Drop Over 200 Feet of Ten Inch Pipe to the Floor, a Distance of About 13 Feet. The Result of this Terrific Strain on the Welded Pipe Joints was One very Small Leak and This was Quickly Stopped with a Torch.

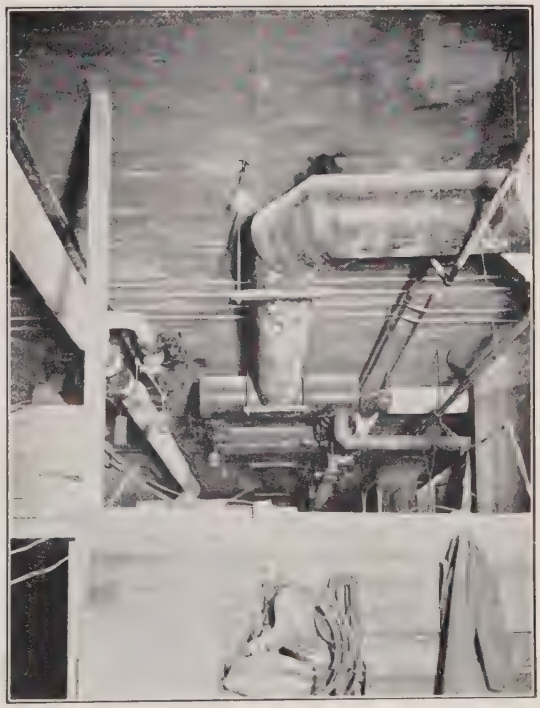


Figure 25—This Photograph Shows a Twenty Inch All Welded Condenser in the Main Twenty Inch Pipe Line. When Connecting up this Pipe Line, It was Found that the Elbow was not Absolutely Square. This Condition was Remedied very Quickly by Using a Cutting Torch to Cut a Slot in One Side of the Ell, Bending the Pipe, and Welding up the Crack with a Welding Torch.

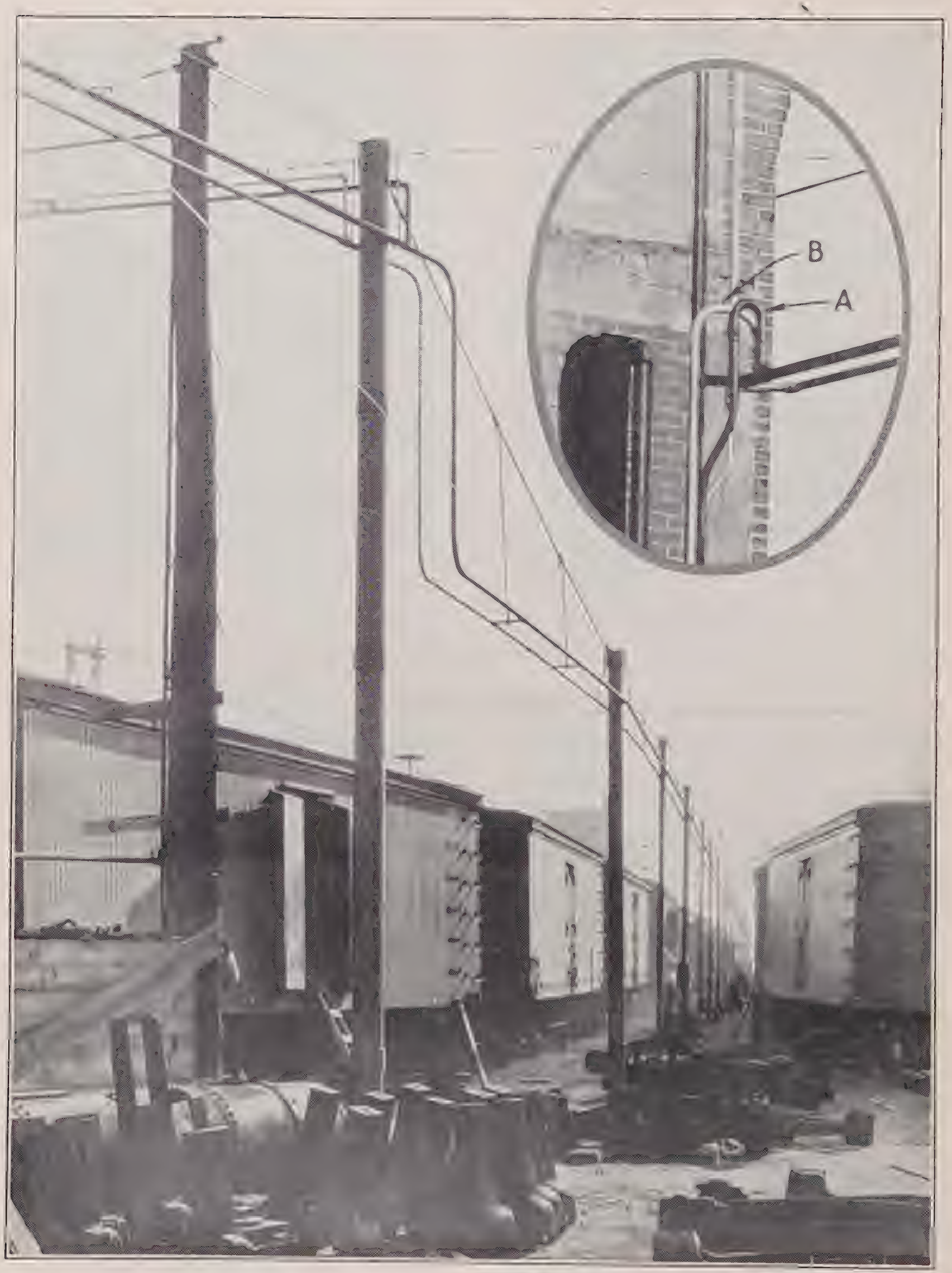
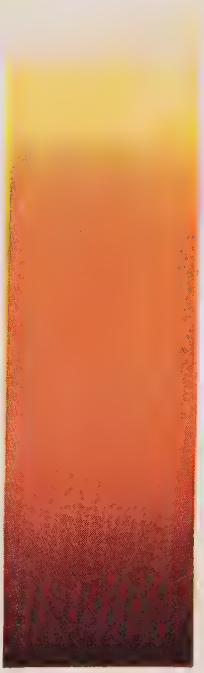


Figure 26—Photograph Showing Acetylene and Oxygen Pipe Lines Supported Overhead Through a Large Industrial Plant. From These Lines Down-Coming Pipes Extend Downward on Every Fifth Pole to Station Outlets Located in Boxes Mounted Upon the Poles. This Arrangement Enables Welders and Cutters, Working Upon Cars, to Connect the Hose Lines to the Torches at Convenient Points. In the Small Oval Shaped View in the Upper Right Hand Corner of the Illustration, a Detail Is Shown of the Manner in Which These Down-coming Pipes Are Connected to the Main Line. A Is the Acetylene Pipe Line and B the Oxygen Line. They Are Taken Off in This Manner in Order to Prevent Water from Draining from the Main Line Down into the Station Outlet.

Lesson No. 7

Miscellaneous Welding Jobs in Steel

A TEMPERATURE color chart has been placed upon the first page of this lesson so that it will occupy a conspicuous place and thereby impress itself to a greater extent upon the mind of the student. It is important that some idea of the relation between the color of a heated piece of steel and the temperature in degrees of the Fahrenheit scale be gained in order that the relation between the melting points of rods, fluxes, etc., particularly in brazing steel, be fully comprehended. It will be noted that temperatures are given in both the Centigrade and the Fahrenheit scales and a few words about these two temperature scales will give an idea of the relation which they bear to each other.

NAMES	COLOR SCALE	CENT.	FAHR.
11 White		1204°	2200°
10 Light Yellow		1079°	1975°
9 Lemon		996°	1825°
8 Orange		941°	1725°
7 Salmon		899°	1650°
6 Bright Red		843°	1550°
5 Cherry or Full Red		746°	1375°
4 Medium Cherry		677°	1250°
3 Dark Cherry		635°	1175°
2 Blood Red		566°	1050°
1 Faint Red		482°	900°

Courtesy of Welding Engineer Publishing Co.

Chart No. 6. This Chart Shows the Relation Between the Colors of Heated Steel and the Temperature in Degrees Centigrade and Fahrenheit.

The Fahrenheit thermometer is ordinarily used in this country and in other English speaking countries to measure the degree of heat and cold. The Centigrade scale, on the other hand, is used largely in countries where the metric system is in use. One of the divisions of the Fahrenheit scale, called a degree, is equal to five-ninths of a division upon the Centigrade scale, also called a degree. In the Fahrenheit thermometer the freezing point of water is taken at thirty-two degrees and the boiling point of water at 212 degrees, the difference between these points being divided into 180 degrees. The Centigrade thermometer, on the other hand, takes the freezing point of water as zero and the boiling point of water as 100 degrees, and divides this difference into 100 equal parts.

Rules for converting the one scale to the other are to be found in almost any engineering hand book and tables are used to a large extent for this purpose. Insofar as the welder is concerned, he will have little occasion to make such changes and they are, therefore, not given here. All of the temperatures given in these lessons are in the Fahrenheit scale.

A temperature color chart can, of course, give nothing more than a graphic suggestion of the relation between the colors of heated steel and the temperatures in degrees. A mental picture of these colors, however, and the relative number of degrees upon the temperature scale will help the welder materially in the work which he does if he will consider the figures, when necessary, in connection with the melting points of both fluxes and rods.

In the welding of steel, of course, the variation in heat colors is not so important, because the metal is actually fused and for this reason no more will be said about these colors in this lesson. They should be carefully memorized however, as they bear an important relation to other work as the course progresses.

Iron and Steel

It is important that the student should now learn the difference between the various grades of steel and between wrought iron and cast iron. No mention has been made as yet of cast iron, because the first lessons of this course apply entirely to steel and the welding of cast iron is fully covered later in the course.

Pure iron is not a commercial metal. It appears on the market in the form of wrought iron, cast iron and steel. In these forms it contains carbon and other impurities. Pure iron is a white metal. It is one of the most common and abundant metals in the earth. It is almost never found in the form of a metal, but in combination with oxygen as a black, red, yellow or brown oxide called ore.

Iron ore usually contains from thirty-five to sixty-five per cent of iron. It also contains sulphur, silica in the form of sand, phosphorus, oxygen and other impurities. The average ores which are found in the United States are about fifty per cent iron. Some of the impurities cannot be eliminated, but carbon and some others have a very beneficial effect upon the iron, giving it greater strength and hardness and other desirable characteristics.

Wrought iron and the very low carbon steels are nearly the same. Wrought iron is made by a puddling process, during which a white hot pasty mass of iron is squeezed and worked until as many of the impurities and as much slag as possible are worked out of it. It is not reduced to a liquid in the course of manufacture and the process leaves from one to two per cent of slag throughout the mass of iron. Wrought iron has an average tensile strength of about forty-eight thousand pounds per square inch and a melting point of about twenty-nine hundred degrees Fahrenheit.

Cast iron has much less strength than either wrought iron or steel, is less pure and is brought to its final shape by melting the iron and pouring it into a mold. The average tensile strength of cast iron is about 15,000 pounds per square inch and its melting point is 2300 degrees Fahrenheit. A typical sample of cast iron contains about ninety-four or ninety-five per cent of iron, three to four per cent of carbon and about two per cent of other impurities.

Steel is much purer than either wrought iron or cast iron. It can be cast by melting it and pouring it into molds, or it may be forged at a red heat to almost any desired shape. Steel normally contains about ninety-eight per cent of pure iron and from one and one-half per cent of carbon down to almost no carbon at all. The balance consists of other ingredients and impurities such as manganese, phosphorus, sulphur, etc.

Carbon is familiar to almost everyone in the form of lampblack, charcoal and graphite, like, for instance, the "lead" of a pencil. It is a very common substance and is present in almost all matter. The oxides of carbon, namely, carbon monoxide and carbon dioxide are gases which have already been explained in connection with the burning of the oxy-acetylene torch. The chemical affinity between carbon and iron is very great and all iron contains some carbon. The last traces of carbon are very difficult to remove. Carbon added to iron increases the strength of the iron to a very great degree, a peculiar fact, because carbon itself does not possess much strength.

Increasing the quantity of carbon removes from the iron some of its ductility and its malleable qualities. It also removes some of its magnetism and some of its electrical conductivity. The influence of carbon in regulating the characteristics of iron and steel is very great, so much so, that steel is ordinarily classified by its carbon content. For instance, steel containing 0.10 per cent of carbon is usually known as soft, basic, open hearth steel. It is ordinarily used for seamless tubing, for truck frames, sheet steel, etc. In its natural or annealed state, it is difficult to machine and it will tear badly in ordinary machine operations.

When the carbon is increased to 0.20 per cent, the steel is generally known as machine steel. This grade of steel machines and forges well. It is used for forgings, case hardened and machined parts where strength is not of supreme importance. It can be rolled into cold rolled forms and can be drawn into tubes.

Steel containing 0.30 per cent carbon is used for structural steel, that is, the steel forming the columns, girders and beams of the frame work of a building, also for bridges, towers and other structures. It is forged into automobile axles and is made into drive shafts, etc. It machines well and can be heat treated to increase both strength and toughness.

When the carbon is increased to 0.40 per cent, a structural steel of greater strength is produced where a high degree of strength and great tough ness is required. After the steel has been annealed it machines well, but it is not tough enough when case hardened to make good transmission gears. It is made up into propeller shafts, drive shafts, crank shafts and is used for many other purposes.

Steel containing 0.50 per cent carbon is still stronger and harder, but otherwise does not differ materially from steel having a slightly lower carbon content. Steel with a carbon content of 0.80 to 0.95 per cent is ordinarily used for springs and is known as spring steel.

Tool steel varies in carbon content from 0.65 per cent to 1.55 per cent. It is carefully tempered according to its carbon content and is, therefore, adapted to various kinds of tools which require definite degrees of hardness. There are, of

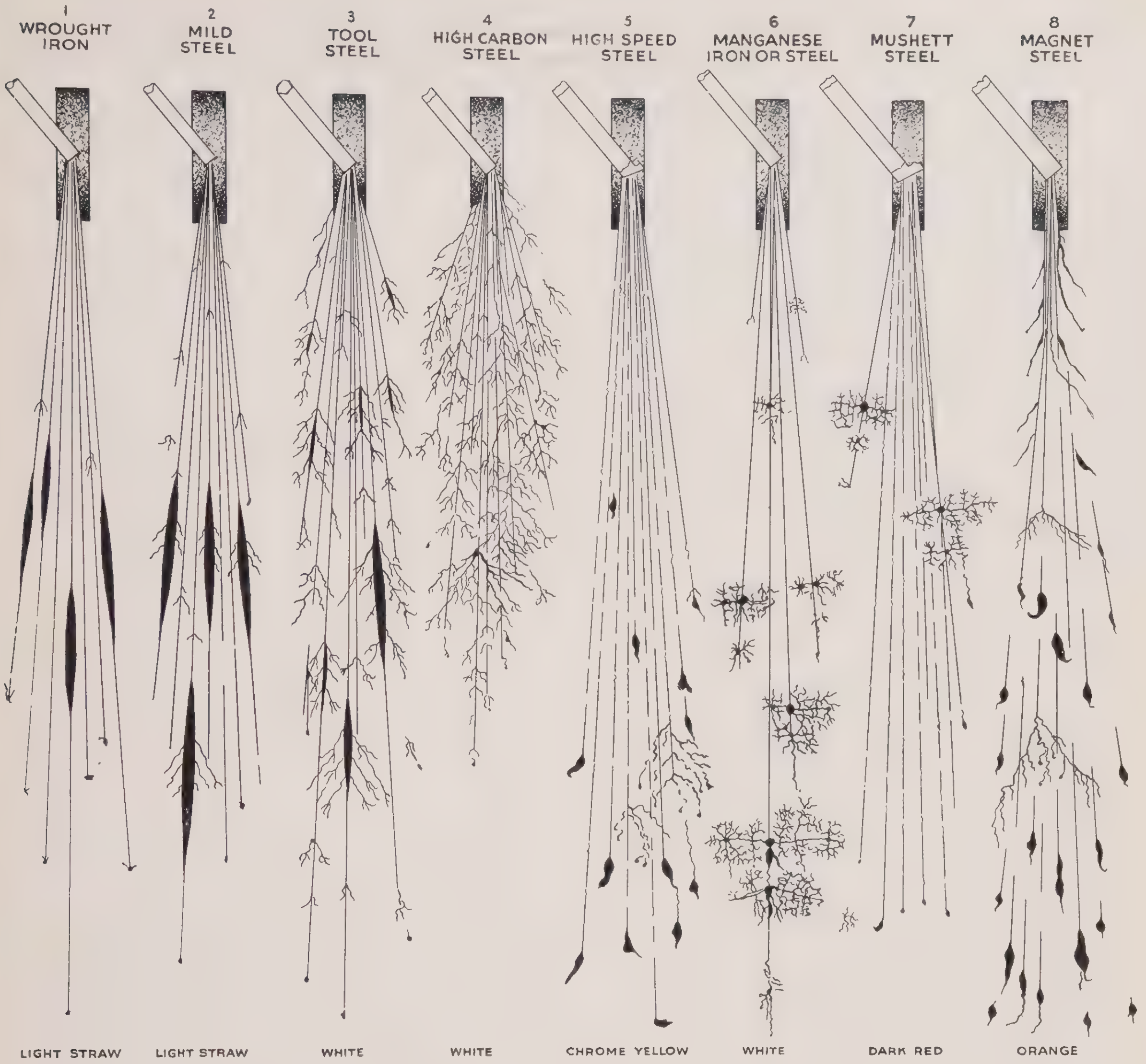


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Figure 1. Sketches Illustrating the Appearance of Sparks Thrown by a Grinding Wheel When Pieces of Various Grades of Steel Are Held Against It.

1. Wrought iron. Sparks thrown from the wheel will follow a straight line. The sparks will become broader and more luminous some distance from the wheel and then disappear in a straight line. The carbon content is from 0.02 to 0.10 per cent.

2. Mild Steel. The steel contains more than 0.10 per cent of carbon, but is a very low carbon steel. The luminous streaks of the iron sparks, indicated by the wide black areas, fork or divide. The carbon content of the iron sparks is burned with explosive violence and breaks away from them.

3. Tool steel of lower carbon content, from 0.50 to 1.00 per cent carbon. The broad, luminous iron lines are less frequent. There is more forking and the forks are often subdivided.

4. The sparks from high carbon steel of the higher grades show practically no iron lines. Forks are very frequent and there are many star-like explosions dividing and subdividing the sparks.

5. High speed steel, containing chromium and tungsten, sparks in quite a different manner. The particles follow a broken or dotted line, as indicated, and just before they disappear the color is chrome yellow, showing no trace of a carbon spark.

6. The manganese spark is clearly indicated. It is quite different from the carbon spark, as will be noted. It appears to shoot out or explode at right angles to its line of travel.

7. Mushett steel is an old high speed steel containing sixteen or seventeen per cent of tungsten, two per cent of carbon and two per cent of manganese. This steel is found among old tools in old established factories and is not a modern high speed steel. There is no carbon spark and only an occasional manganese spark. The lines are broken and the sparks are very dark red.

8 Magnet steel. This sketch shows a steel used in the manufacture of magnets. This, as will be seen, produces an entirely different spark which can be easily distinguished from any of the others.

course, many alloy steels besides the carbon steels, such as nickel steel, nickel chromium steel, chromium steel, vanadium steel, tungsten steel, manganese steel, molybdenum steel, etc., each having characteristics which make it particularly suitable for certain uses. These alloy steels are considered in later lessons.

As the carbon content of steel increases, its tensile strength increases and its melting point becomes lower. For instance, the tensile or pulling strength of pure iron is in the neighborhood of 35,000 pounds. Every one-hundredth of one per cent of carbon added to the iron increases its tensile strength about eight hundred pounds up to a maximum of approximately one per cent. The melting point of a low carbon steel is approximately 2700 degrees Fahrenheit, while that of a medium carbon steel is about 2600 degrees and that of a high carbon steel about 2500 degrees. It will be seen, therefore, that as the carbon content increases the melting temperature becomes lower.

Determining the Composition of Steel by Its Sparks

One of the difficulties which a welder frequently encounters is the determination of the amount of carbon in a piece of steel as well as some of the other elements of which it is composed. This is rather a difficult matter unless a very careful microscopic examination is made, but for practical purposes insofar as the welder is concerned he can gain an idea of the characteristics of steel by watching the sparks made when a piece is held in contact with a grinding wheel. The sparks which are thrown from the wheel are characteristic of those elements, which are combustible in the steel.

In 1911 Mr. John F. Keller, Steel Specialist of the Engineering Extension Department, Purdue University at Lafayette, Indiana, worked out some spark tests of various grades of steel which will undoubtedly be of use in determining the characteristics of a piece to be welded.

The illustrations have been redrawn as nearly like the original sketches as possible and, with the descriptive matter, the student should quickly learn the appearance of each characteristic spark. These sketches and the description of them are being republished with the kind permission of Mr. Keller.

Butt Welding an Angle Iron

The first job of welding which will be discussed in this lesson is the butt welding of a six by six by one-half inch angle iron. This job is illustrated in Figure 2, a sketch showing the required preparation of the joint and the method of tack welding, and in Figure 3, a photograph of the completed weld.

The edges of each piece of angle iron should be bevelled with the cutting torch to an angle of 45 degrees with the side of the irons, or when placed together to an included angle of 90 degrees. At the heel of the angle, as illustrated at A, Figure 2, this bevel should be slightly greater than 90 degrees to assure penetration clear through to the bottom of the heel.

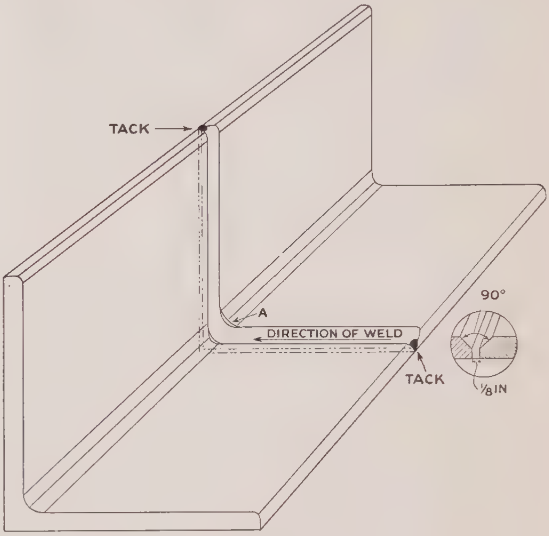


Figure 2—Sketch Showing a Six by Six by One-half Inch Angle Iron Bevelled with the Cutting Torch and Tack Welded in Position to be Butt Welded. Note the Enlarged Section of the Vee at the Heel of the Angle Marked "A," to Assure Full Penetration at this Point.

A welding torch should be used to clean up the edges of the cut surfaces by melting and causing to flow away, the oxide left by the cutting torch.

An essential part of the equipment of every welding shop is a flat, planed bed plate. This may be an old planer bed, or the bed plate of some other machine which is no longer in use, or it can often be obtained from scrap machinery. It should be properly mounted upon supports, so that it is solidly held at a convenient height.

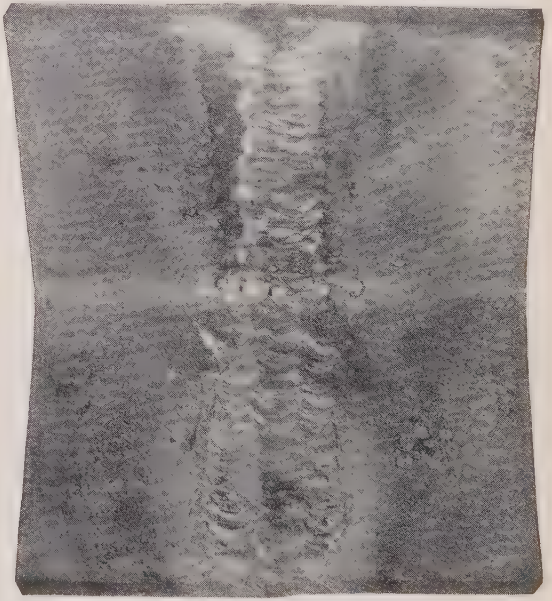


Figure 3—Photograph Showing the Completed Butt Weld Between Two Pieces of Six by Six by One-Half Inch Angle Iron.

A piece of asbestos paper should be laid over this bed plate to prevent radiation of heat and the two pieces of angle iron set up in line and clamped with C clamps securely to the plate. If it is desired to have the completed length of the two pieces exact about one-eighth of an inch should be left between the edges. This will allow for expansion and subsequent contraction.

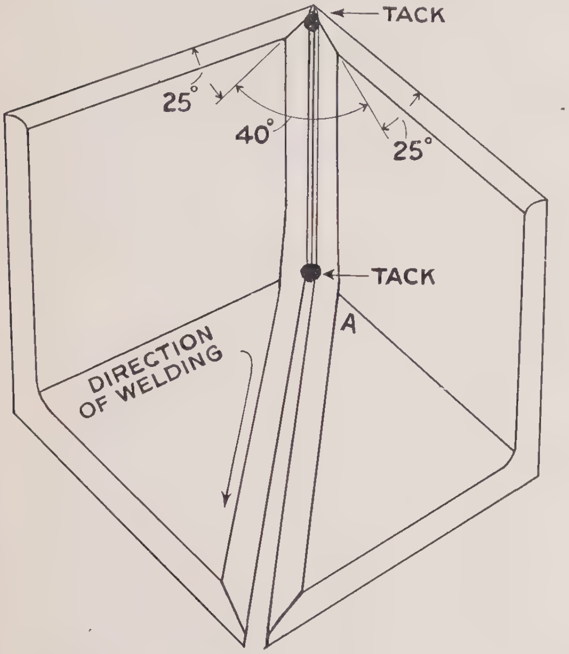


Figure 4—Sketch Showing the Corner Weld of an Angle Iron Frame. This Sketch Indicates the Method of Cutting the Pieces of Angle Iron with the Cutting Torch to Give the Correct Bevel and the Manner in Which the Two Pieces Are Tack Welded Together.

The two pieces should now be tack welded together, first at the top of the angle, as shown in Figure 2, and then at the lower front edge toward the welder.

He should start the weld at the front edge of the horizontal leg of the angle iron and weld a bead along the bottom of the vee to the heel, or the back edge of the angle iron.

Beginning at the front edge again, a heavy bead of metal almost to fill the bevel should be deposited. This layer of metal should be carried all the way across the leg to the heel of the angle. When this has been completed, the weld should be started again at the front edge of the leg of the angle iron nearest the welder and enough metal added to produce the desired reinforcement.

It may be necessary to weld across the bevelled section four times in order to fill the vee to the desired height. The weld at the heel of the angle iron is usually a little wider than the balance of the weld, because of the additional thickness at this point and the necessity for melting down the edges so that full penetration to the bottom of the angle is secured.

The vertical leg of the angle iron should now be welded and this weld should be started at the base of the heel of the angle and carried to the top of the piece. It is best to build the vertical weld to the full section including the reinforcement as the weld progresses upward so that it will be unnecessary to go over the vertical portion of the weld a second time.

Welding the Corner of an Angle Iron Frame

This job was accomplished for these sketches and photographs with pieces of five by five by three-eighths inch angle iron. The pieces should be cut to an angle of approximately forty-five degrees and the edges of the steel bevelled with a cutting torch. The bevel on the vertical leg of the angle must be more than forty-five degrees, because when the two pieces of angle iron are fitted together a forty-five degree angle would make a tight joint allowing no bevelling in which to make the weld. If, therefore, the angle of the bevel with the side of the vertical leg of the angle is twenty-five degrees when the two pieces of iron are fitted together at ninety degrees, the surfaces of the bevels will make an included angle between them of forty degrees. This is clearly indicated in the sketch, Figure 4.

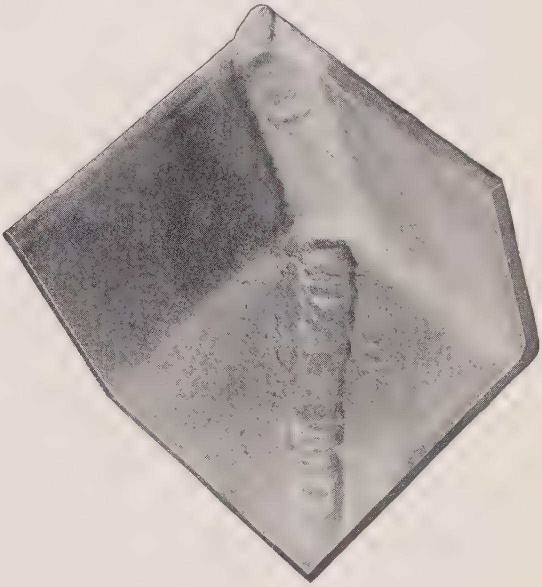


Figure 5—Photograph Showing the Completed Corner Weld of an Angle Iron Frame.

After the pieces have been properly bevelled and the edges are thoroughly cleaned of oxide left by the cutting torch, they should be placed together so that the near edges of the two horizontal legs are spread slightly. This will allow for expansion and subsequent contraction of the metal which will tend to draw these legs together just as the plates were drawn together by the welded seam as it progressed, described in the first part of Lesson No. 6. The distance apart which these edges should be spread, of course, depends entirely upon the size and thickness of the angle iron.

In the particular instance in connection with this job, the spread amounted to approximately one-eighth of an inch over a six inch length. This is also clearly indicated in the sketch, Figure 4. No absolute rule can be made for the distance which must be allowed, because the heat of welding will cause the angle iron to draw an amount depending entirely upon the shape, length, thickness and size of each angle iron. It is a matter of experiment, but if the welder will take a little pains to determine just how much the allowance should be for each case, he will have no particular difficulty.

When the two pieces of angle iron are set on a piece of asbestos paper on top of the bed plate and proper allowance for expansion has been made, they may be held securely in place with C clamps. They should then be tack welded at the top and bottom of the vertical leg. The weld should begin at the heel *A* of the horizontal leg of the angle, and continue to the front edge of the angle, filling about one-half to two-thirds of the vee while welding the first layer.

Approximate Melting Points of Metals and Alloys

Substance	*Degrees Fahrenheit*
Wrought Iron	2900
Iron (pure)	2760
Steel, mild	2700
Nickel	2640
Steel, medium carbon	2600
Steel, high carbon	2500
Monel Metal	2400
Iron, Cast	2300
Iron, Malleable	2300
Copper	1980
Bronze, Phosphor	1920
Brass, Common Yellow	1652
Bronze, Tobin	1625
Brazing Spelter (Granulated)	1440 to 1620
Silver Solder	1325 to 1600
Bronze, Manganese	1600
Aluminum	1175
Antimony	1150
Zinc	786
Babbitt	500 to 700
Lead	620
Solder	350 to 550
Tin	450

Care should be taken that the weld penetrates clear through to the bottom of the lower leg. At the heel of the angle iron particular care should be taken to fuse the metal all the way through this heavier section. This precaution is emphasized because it is difficult to make the weld in this section of the angle and it requires more attention than the rest of the angle. It will be necessary to weld across the bottom or horizontal leg of the angle three times. The first time the edges should be melted and the vee filled about one-half full. The second time the vee should be filled flush with the surface of the angle and the third time the necessary reinforcement built up.

When the horizontal weld has been completed, the pieces should be turned if possible so that the leg which was in a vertical position may be welded also in a horizontal position. The edges should be melted into the vee and well fused together and the weld should then proceed in the same manner as the one already described.

It is entirely possible, however, that where a large frame is to be welded, it would be found impossible to turn these pieces so that this weld could be made in a horizontal position. In this event, the vertical leg should be welded in a vertical position, as described heretofore, for the butt weld of the angle iron. The vertical weld in a corner, however, is more difficult than a vertical weld would be when two pieces of angle are butted together, as heretofore described. The reason for this is the fact that the heat of the torch is reflected and flared back against the tip, causing the tip to be heated considerably and the heat of the weld deflected toward the operator.

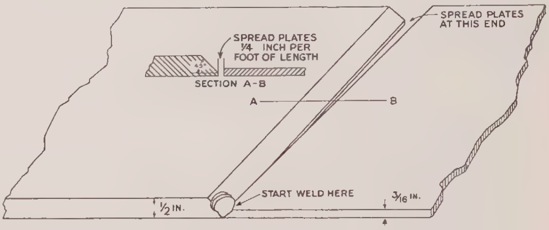

SPREAD PLATES AT THIS END
SPREAD PLATES 1/4 INCH PER FOOT OF LENGTH
45°
SECTION A-B
A
B
START WELD HERE
1/2 IN.
3/16 IN.

Figure 6—Sketch Showing the Preparation Required for Welding a Three-sixteenths Inch Steel Plate to a One-Half Inch Plate. The Sketch also Illustrates the Manner in Which the Plates Should Be Spread

In bevelling the weld at the heel of the angle, care should be taken to make the bevel wider so that the flame may reach well down into this corner to assure complete fusion through the metal. This additional width of cut is shown at A in Figure 4.

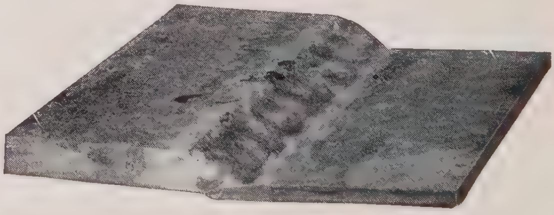


Figure 7—This Photograph Shows Two Pieces of Three-sixteenths Inch and One-half Inch Plate Which Have Been Welded Together. The Joint Is Typical of a Seam of this Kind Between Different Thicknesses of Metal.

Figure 5 shows a photograph of the completed corner weld. The other four welds in the corners of an angle iron frame are made in similar manner when it is necessary to use four separate pieces of angle iron. A frame is often made, however, by cutting vee shaped pieces out of the horizontal leg of the angle iron and bending the vertical leg to a right angle at each corner. This brings the mitered sections of the horizontal legs together ready to be welded. This latter method for making a frame is somewhat easier than that already described, and requires less welding.

The method, however, of welding is identically the same whether the vertical leg is bent or is welded from the separate pieces.

Welding Two Different Thicknesses of Metal

The specific work in this instance consisted in welding a three-sixteenths inch plate to a one-half inch plate; these are the thicknesses which are illustrated in the sketch, Figure 6, and the photograph, Figure 7. The heavier piece of steel should be bevelled to an angle of approximately forty-five degrees with the cutting torch, after which the oxide formed on the edges should be melted away with the welding tip as already described. If the two pieces to be welded together are of any great length, allowance must be made for the expansion and subsequent contraction of the metal by spreading the plate at the far end of the seam a distance equal to one-quarter inch per linear foot of seam.

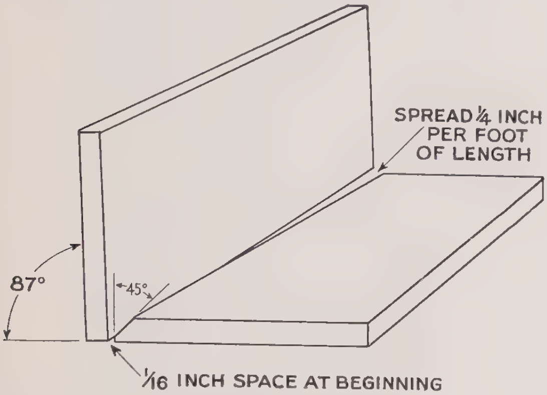

SPREAD ¼ INCH PER FOOT OF LENGTH
87°
45°
1/16 INCH SPACE AT BEGINNING

Figure 8—Sketch Showing the Method of Preparation and the Separation of the Seam in Making an Inside Corner Weld Between Two Pieces of Three-eighths Inch Steel Plate. Note That Only One Plate Is Bevelled and That the Vertical Plate Is Set Slightly Out of Vertical to Allow for Contraction as the Weld Cools.

If the pieces are short they may be successfully welded by allowing about one-sixteenth of an inch between them for the entire length of seam. If this is done the pieces should be tack welded at one end and the weld begun at the other end. In welding a heavier piece of steel to a lighter thickness, the most important thing to be remembered is that the flame must be directed against the heavier piece instead of the lighter sheet. The heavy piece of metal requires more heat to maintain it at the point of fusion than the thin piece and the flame must therefore be so directed that the greater part of the heat will be transmitted to the thicker piece of metal.

When starting the weld, however, the flame should be directed momentarily against the thin piece to bring it to the point of fusion. The flame should then be turned toward the thicker piece and the wall of the bevel slightly melted down into the vee formed by the bevel. The weld should be built up to the desired thickness the first time across the weld.

Making An Inside Corner Weld

Three-eighths inch steel plate has been used in this example. One of these pieces is a horizontal plate, which should be bevelled with the cutting torch to an angle of approximately forty-five degrees, and the oxide melted away with the welding torch in the usual manner. The other plate is the vertical plate forming a right angle seam. The bevelled horizontal piece is placed on asbestos paper on the bed plate and clamped in position. The vertical plate should then be placed in position, as illustrated in Figure 8. The far end of the seam between the two pieces should be spread approximately one-quarter inch per foot of length and the vertical piece should be tilted slightly away from the weld so that when the weld is completed contraction of the metal will draw it into a perpendicular position. The weld should be started at the near end of the seam and the vee should be filled flush with the surface of the horizontal plate for a distance of approximately one and one-half inches. The torch should then be returned to the beginning of the weld and a fillet built up giving the desired reinforcement. This is clearly shown in the photograph of the finished weld, Figure 9. This process, that is, welding flush for an inch and one-half and then building up the fillet, should be repeated until the full length of the weld has been completed.

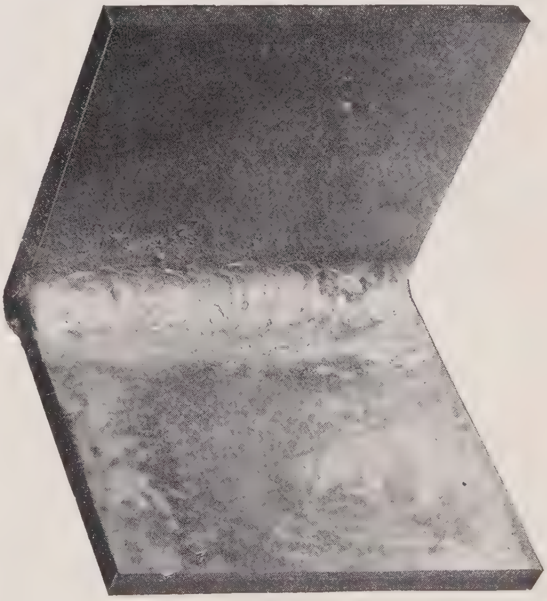


Figure 9—Photograph Showing the Completed Weld Between Two Pieces of Three-eighths Inch Steel Plate. A Fillet Has Been Built Up Making an Inside Corner Weld Which Is Strong and Serviceable.

Making An Outside Corner Weld

Three-eighths inch steel plate has been used in the example of this type of weld between two pieces of steel. These pieces are placed together at right angles in order that the outside corner may be welded. It is not necessary to bevel the plates, because if placed together so that the near inside corners are in contact the square edges of the plates make an angle of ninety degrees. As with all long seams, it is necessary to spread the far edges of the seams apart so that when the weld progresses the seam will not be warped or crushed out of shape because of contraction strains. The far end of the seam between the plates should, therefore, be spread about one-quarter of an inch to the foot, as illustrated in Figure 10.

The weld should begin at one end of the vee formed by the square edges of the plates nearest to the welder. The edges of the plates should be melted down and made to flow into the vee, partially filling it for a distance of about one and one-half inches. The welder should then begin again at the beginning and build up a weld for this distance to the height giving the correct amount of reinforcement for the purpose. This process is repeated until the weld is completed. The thickness through the weld should be at least equal to the thickness of the plates. This method is illustrated in detail in Figure 10 and a photograph of the completed weld is shown in Figure 11.

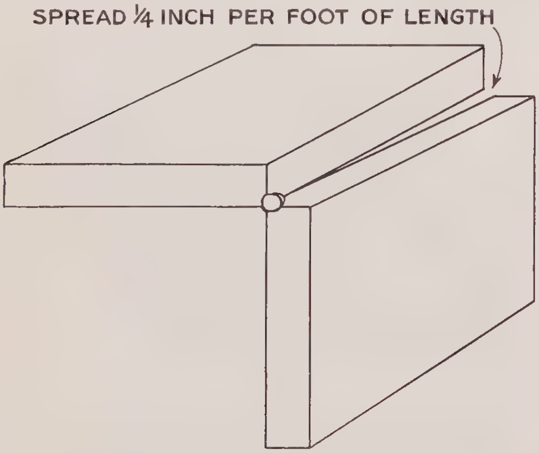


Figure 10—Sketch Showing the Method Used to Make an Outside Corner Weld Between Two Three-eighths Inch Steel Plates. They Should Be Separated at the Far End of the Seam, as Usual, to Compensate for Contraction and, if Possible, Some Sort of a Jig Should Be Provided to Hold Them in Place During Welding.

In making an outside corner weld in this manner, it is desirable that the plates be held in some kind of jig. This may consist of an angle iron, supported upon suitable supports, and two external angle irons held securely with clamps. Such a jig is illustrated in Figure 12 and will be found very convenient.

Welding a Hole Closed

A piece of steel plate five-eighths of an inch in thickness was selected and a hole approximately two and one-quarter inches in diameter was cut in the center of the plate with a cutting torch. The plate was placed in a horizontal position resting on two fire bricks so that the hole in the plate was between the two bricks. The hole was welded closed from only one side of the plate.

Welding was started on the right hand side of the hole, the top edge of the steel being melted and allowed to run down and collect in a small bead at the bottom of the plate. Melting down the sides of the steel in this manner was continued for approximately one-quarter of the circumference of the hole. The welding rod was then used to build the bead out very slightly. When the bead had been built out about one-eighth of an inch, the flame was removed from that spot and the next quarter of the circumference of the hole was melted down in a similar manner and the resulting bead slightly built out.

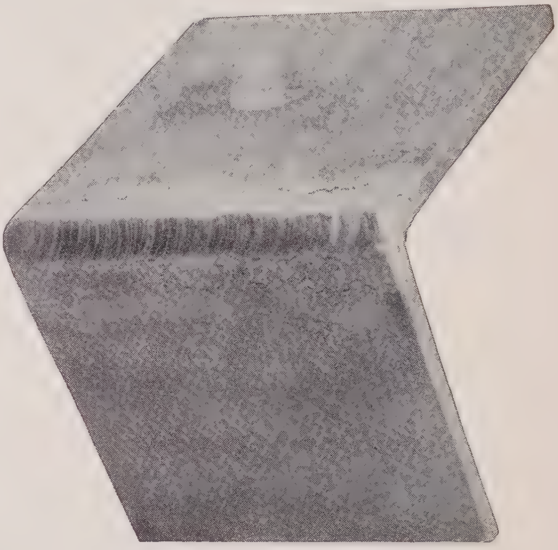


Figure 11—Photograph of a Completed Outside Corner Weld Between Two Pieces of Three-eighths Inch Steel Plate.

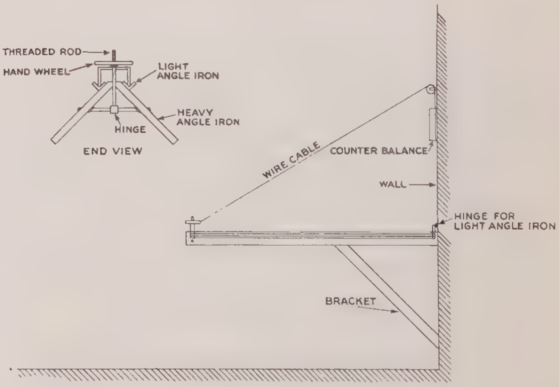


Figure 12—A Typical Jig Used to Hold the Steel Sheets in Place During Welding.

The first quarter having cooled somewhat, the flame was again played upon the deposited metal and more steel from the welding rod added to it. Next the quarter of the circumference on the other side of the original starting point was treated in a similar manner.

This practice of alternating from one quarter to another was carried on until finally the entire hole was closed by means of a thin layer of steel. A heavy bead was now built along one side of the hole for a distance of about one and one-half inches. This bead was built out to approximately the center of the hole and built up to a point slightly below the top of the plate. Similar beads were constructed along either side of this first bead and continued around the circumference of the hole until finally the opening was closed.

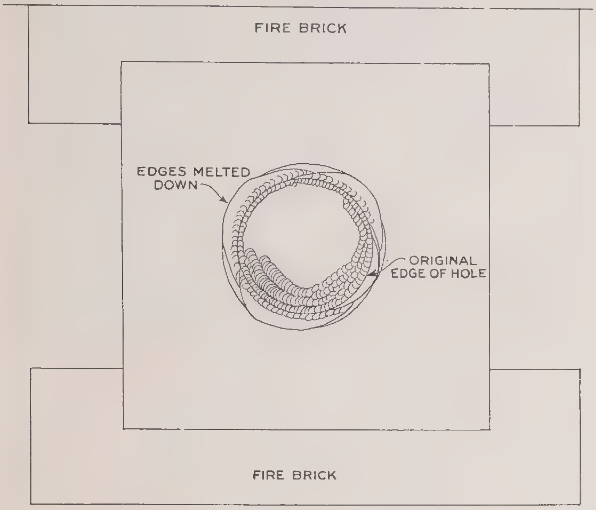


Figure 13—Sketch Showing a Two and One-quarter Inch Hole Cut in a Five-eighths Inch Steel Plate and the Manner in Which This Hole Should Be Closed by Welding to Make a Sound, Strong Job Free of Cracks and Strains.

The torch was then played over the deposited metal in order to make certain that all of the various beads were well fused to each other and to the sides of the hole. More material was then added and the weld built up to the finished level. This weld was not reinforced but was made flush with the top of the plate.

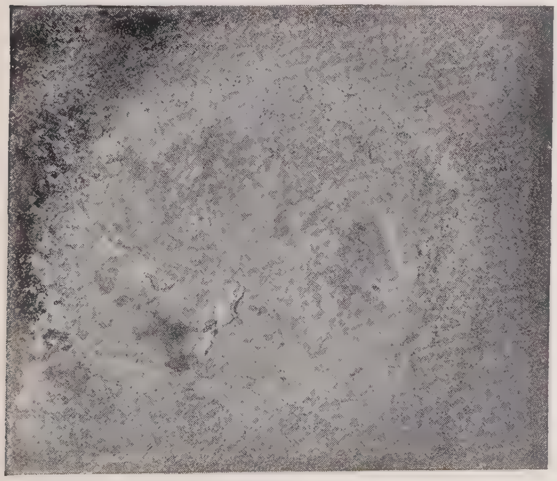


Figure 14—Potograph Showing the Finished Weld of a Hole in a Plate. This Weld Was Made With the Plate in a Horizontal Position as Described.

It is important to remember in filling a hole in this manner to keep the flame of the torch pointing towards the sides of the hole rather than at the bottom. This will prevent overheating the center of the hole and making the metal so soft at this point that it will sag.

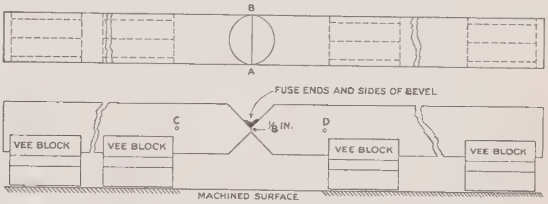


Figure 15—Sketch Showing the Cut Out or Veed Section of a Round Shaft Prepared for Welding. The Vee Should Make a Chisel Edge, Like That Shown at A-B and Not a Point. The Shaft Is Shown Resting Upon Vee Blocks Upon a Planed Bed Plate.

If the plate were in a vertical position, welding it closed would be accomplished by starting at the lowest part of the hole and continuously laying a bead of metal along the lower part of the circumference. The puddle in this instance should be kept at the lowest point of the weld and the beads should be built evenly across the hole rather than up one side or the other.

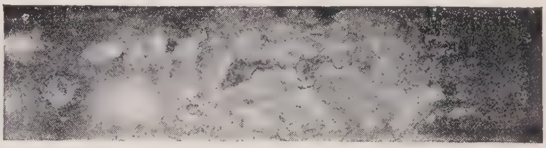


Figure 16—Photograph Showing the Completed Weld in a Round Shaft. No Finishing Whatever Has Been Done and the Shaft Is Exactly as It Was Left By the Torch.

Welding a Round Steel Shaft

A cutting torch should be used to cut the ends of the shaft to the shape of a double vee bevel, as shown in the sketch Figure 15. The shaft should not be cut to a point, but to a chisel edge indicated at A-B. The metal should be cut to a blunt vee, having a straight section about one-eighth of an inch in thickness, and not to a feather edge. Before cutting the shaft in preparation for welding, it is always good practice, if the shaft must be of a definite length, to make two center punch marks, C and D, one on each side of the break at an even number of inches apart. These punch marks should be made exact when the parts of the shaft have been fitted together to its original length and will indicate, when the job is finished, whether or not the correct allowance has been made for expansion.

After cutting the vee a certain amount of oxide will be left upon the cut edges and this should be cleaned off with a grinding wheel, chipped with a chipping tool, or melted off with a welding tip.

If a welding tip is used, the cut edges should be heated at the top of the piece and the molten metal allowed to run to the bottom and to drip away. The torch should be moved downward along the cut surface melting the oxide away until the bottom is reached.

Cast iron vee blocks are a necessity in welding shops. When these are set upon the machined bed plate with the legs of the blocks in contact with a straight steel bar, the blocks will be in line. If the shaft is set in the vee blocks, it too will be in a straight line, parallel to the base plate.

When the shaft is thus lined up, the distance between the two center punch marks should be equal to the original even number of inches. This will indicate that the original length has been maintained even though the bevelling has entirely cut away the broken surface. The two pieces should then be tack welded together at the edges of the bevel. The bottom of the vee should be melted and filled in by melting down the sides of the vee until a good sized puddle is formed at its bottom. The far side of the vee, that is, the side farthest away from the operator, should be built up a slight distance and then the torch moved over to the near side and an equal amount of welding rod fused into place. In this manner work should progress alternately from side to side until the vee is completely filled or built up.

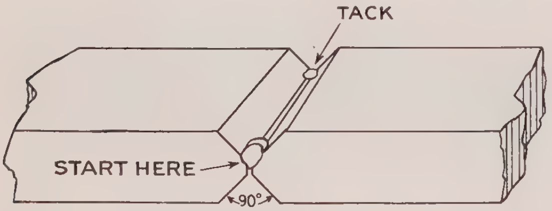


Figure 17—Sketch Showing the Double Vee of a Rectangular Bar. Cutting of the Bevel May Be Accomplished With a Cutting Torch or May Be Machined If Desired. If the Torch Is Used, Care Should Be Taken to Remove Oxide Either With a Welding Torch, or With a Grinding Wheel. If a Chipping Hammer Is Available, the Oxide may be Chipped Away and then the Surface Ground Until Clean.

The weld should be reinforced by increasing the thickness of the shaft or in other words, building up the weld metal sufficiently to provide for any necessary machining.

After completion of the first side of the shaft, the welding torch should be used to melt off the surface metal which has run over the side of the vee. This will give the weld a neat appearance at the sides of the shaft and eliminate any slag which may have collected at these points. The shaft should then be turned over so that the vee opposite that already welded is uppermost, and the flame played along the sides and the bottom of the vee until slag which may have collected is melted away.

Particular pains should be taken to see that the extreme bottom of the vee is thoroughly fused and flowing freely, thus assuring complete penetration into the weld which has already been made. The method of fusing and building up the metal on this side of the shaft is identical with that already described. More heat is required when first fusing the sides and the bottom of the vee than after the vee has been partially built up.

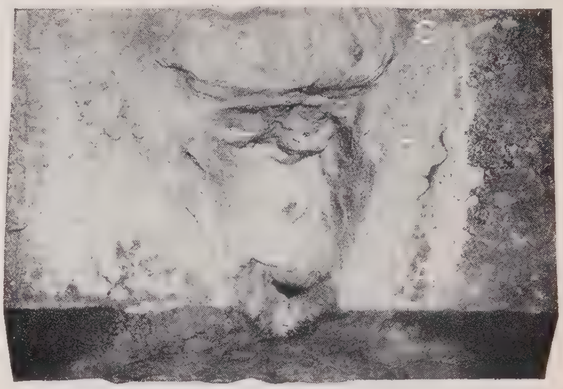


Figure 18—Photograph Showing the Partially Completed Weld in the Rectangular Bar. The Layers of Metal Have Been Left to Show the Method of Their Application. At A the Veed Portion of the Bar is Shown, Which has been Tack Welded only. At B the First Layer of Metal Has Been Melted From the Sides and Fused to the Bottom of the Vee and at C is the Final Layer of Metal Welded in Place. If Reinforcement were Necessary, Still Another Layer of Metal Would Be Required to Build the Section Up to the Full Reinforced Thickness.

When the weld is completed, as heretofore described, the shaft will usually be found slightly out of line. This can be quickly remedied by straightening the shaft while hot.

Welding a Rectangular Bar

The bars illustrated are one and one-half inches in thickness and three inches in width. The ends of the bars should be bevelled with the cutting torch to a double vee, or by machining the ends of the bars to this shape, shown in Figure 17. If a cutting torch has been used to cut the vee, the slag or oxide left by the torch should be removed by melting it away with the welding torch, or by grinding it off with a grinding wheel. If

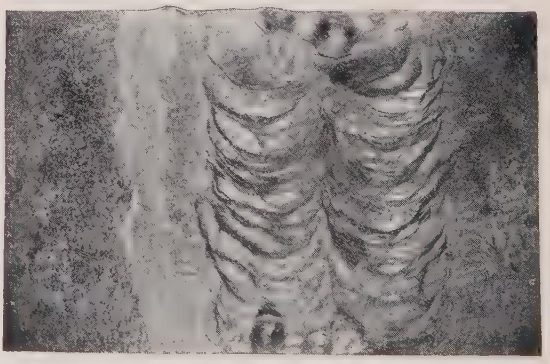


Figure 19—This is a Photograph Showing the Completed Weld of the Rectangular Bar. This Bar Was Not Reinforced, But the Weld Was Built Flush With the Surface.

it is necessary that the finished bar be of exact length, two center punch marks should be placed, one on each side of the bars, before they are beveled, as already described. The two pieces should be supported upon fire bricks and carefully lined up. In this instance, it is advantageous to have the vee portions of the bars directly over a fire brick, as the brick will reflect the heat to the weld and thus offset some of the heat conductivity of the shaft.

Before starting to weld, the ends of the two bars should be heated with the torch for a few moments. The edges of the veed portions of the bars should next be fused together and the sides of the vee melted down as described in the welding of the round shaft. The torch should be directed against each side of the vee as evenly as possible, so that an equal amount of metal will be melted down from each side. In this manner each end of the bottom of the vee should be tack welded together. After this has been accomplished, a bead should be welded across the bottom of the vee.

Building up of the weld should now take place on the near side of the vee for approximately one and one-half inches, that is, one-half the length of the weld. A similar weld should then be built up on the far side of the vee, making sure that the two sections are thoroughly fused to each other. If the length of the weld is greater than three inches, the layer of steel should be built up in three sections. Under normal conditions a layer of this kind should be built for a length of not more than one and one-half inches at a time. Another layer should then be built upon the first section and followed by a second layer on the second section and so on until the weld metal has been built up to the surface of the bar. Additional reinforcement can then be made if required. In this piece it would normally take two layers to build flush with the surface and a third layer for reinforcement.

The bar should be turned over and the flame directed along the bottom of the seam sufficiently to be sure that complete fusion is accomplished and that all oxide has been eliminated. When this has been done the sides of the vee may be melted down in a manner similar to that used on the first side and the weld completed in layers as described. The amount of metal which should be melted down from the sides is roughly enough to fill the vee half full.

Approximate Weight of Metals and Alloys

Substance	*Weight in Lbs. Per Cubic Inch*
Lead	.411
Copper	.322
Phosphor Bronze	.321
Nickel	.319
Monel Metal	.318
Brass (Common Yellow)	.303
Tobin Bronze	.303
Manganese Bronze	.302
Iron (Pure)	.283
Wrought Iron	.283
Steel	.282
Tin	.263
Cast Iron	.260
Malleable Iron	.260
Zinc	.250
Antimony	.242
Aluminum	.096

If the bar could not be reached from the top and bottom, it would then become necessary to weld each vee from the side, making vertical welds. In this instance the weld should be started at the bottom of the vee and built across in a generally similar manner to that described for the hole in the plate. With this metal as a base, the weld should then be built up horizontally, filling the vee completely as the weld progresses upward. A very convenient method of supporting the bottom of a weld in a case of this kind is to clamp a carbon plate to the bottom of the bar directly under the veed bevel. This carbon plate forms a base upon which to build the metal out and makes it a little more convenient to accomplish the result. Carbon plates for this purpose are a commercial product and can be secured from suppliers of welding and cutting equipment.

Job Sheet No. 7

In this lesson the explanation of the various jobs described and illustrated has been so complete and exact that further explanation is believed unnecessary in this job sheet. The student has now reached the point where he will have some preference as to the particular job which he desires to do. He may feel that he should apply his efforts at this time to some one of these jobs rather than others, because he may believe that the particular practice work which he selects is more necessary to his progress.

For this reason the job required in this lesson will be optional with the student. He may select any one of the jobs described in the lesson and perform it in a satisfactory manner.

After the job has been done a section of the weld should be sawed out with a hack-saw, placed in a vise with the side from which the weld was made facing forward and the jaws of the vise flush with the edge of the weld. The piece should be bent away from the operator to an angle of ninety degrees. If it will stand this test without breaking, the weld may be considered good. It should then be bent back and forth until it does break, and if the break occurs in the weld it should be carefully examined to note any inclusions of slag, gas pockets or other defects which might account for weakness.

If the weld is a right angle weld, that is, either an inside corner weld or an outside corner weld, it may be straightened out flat as a test by squeezing it in a large vise. A careful examination of a section of a weld which has been cut from the work and broken, will often give the student much information relative to the results of his method of manipulation of the torch, the rods and his control of the heat of the flame.

In this lesson no mention has been made of the particular method of welding to be used in accomplishing the jobs described. The movement of torch and the rod is not of great importance, providing both are skilfully handled. One welder may find that a particular movement is more advantageous in his case than another, or on the other hand, he may use several movements upon one job. For these reasons the movement of the torch is not specified but left to the choice of the welder.

Questions:

1. In what form does iron come from the mines?
2. What is the difference between wrought iron and tool steel?
3. How may the relative carbon content of two pieces of steel be determined in the ordinary garage or machine shop?
4. Why is asbestos paper placed under a piece of metal to be welded?
5. Tell how the pieces of angle iron should be prepared for welding when making a frame with welded corners.
6. List all of the equipment, giving sizes of tips and rods used in preparing and making the corner weld of an angle iron frame. The angle iron to be used measures eight inches on each leg and is one-half inch thick.
7. After bevelling a shaft with a cutting torch, is any further preparation necessary before welding is commenced?
8. What is a vee block?
9. When welding two long steel plates together, how are expansion and contraction taken care of?
10. Describe the proper manner in which to weld closed a hole in a steel plate?

Lesson No. 8

Welding Tanks

THE subject of this lesson is an interesting and important one to the welder who works in a small shop and also to the man who is employed in a large industrial plant. In the industrial plants and on the railroads the size of the tank, the thickness of the metal, the pressure required and other details of this kind, would, in all probability, be figured out by the engineering department, and the welding department would have little to do with this part of tank construction.

In the smaller shops, however, and in the country, the welder is often asked to construct a tank of a certain capacity and in such instances he must do the figuring and the designing of the tank, as well as the actual welding. For this reason, he should know something of the general principles of tank construction, even if only in a rough way. Of course, larger tanks, and particularly those containing pressure, should be designed by an experienced engineer, but there are many tanks in which the pressure is merely the weight of the liquid content of the tank. In such cases the welder can just as well determine the governing figures as not.

In any event, a knowledge of such principles and figures would materially assist him in the construction of tanks whether or not he is responsible for the details of design. Pressure tanks, that is those containing air, gases, or liquids under pressure, must be very carefully designed to meet the requirements of the various municipal and state authorities, and the boiler code of the American Society of Mechanical Engineers, as well as the specifications and requirements of the Underwriters' Laboratories.

Boiler Construction Code

In many states the state law, or the actual practice of the authorities in charge of pressure tanks, requires that such tanks be constructed in accordance with the American Society of Mechanical Engineers boiler construction code. A part of this code refers particularly to the construction of unfired pressure vessels, or in other words, tanks under pressure which are not used in connection with heat and fire. These rules do not apply to pressure vessels or tanks which are subject to Federal inspection and control; to locomotives, or to tanks which are intended to contain only water under pressure for domestic supply purposes.

These rules do not apply, in general, to tanks of any diameter, or length, for the storage of air, or gases, where the pressure is 15 pounds per square inch or under. Formulas are given to fix the pressures, diameters, volumes and working temperatures of tanks which are exempt from the rules.

These formulas show that the pressures permitted in exempt tanks are subject somewhat to their diameters and volumes and in some specific instances slightly exceed 15 pounds per square inch.

Storage Tanks Not Under Pressure

It will, therefore, be seen that these rules do not cover a large number of storage tanks, where liquids are to be stored, which are not under pressure. If, however, these liquids are inflammable and near insured property, the tanks would normally come under the rules and requirements of the Underwriters' Laboratories, as the inflammable liquid would represent a fire hazard if a tank was not strong enough to hold it. There are a great many tanks used nowadays for the storage of oil and gasoline, both above and under ground. These represent a large field for oxy-acetylene welding, because of the fact that when the welded tank is completed it is absolutely tight.

A riveted joint will almost always leak gasoline or oil to a certain extent, and the loss of such liquids, through leakage and evaporation, is very much larger than is generally supposed. There are also a great many tanks of the open top variety used for dipping, washing and other such purposes, which contain water or other liquids. In many instances these tanks must be constructed of galvanized iron, or if not too large, they are galvanized after they are welded.

In the oil industry, particularly around refineries, there are many tanks used which have to stand much higher temperatures, and very high pressures. Such tanks, of course, must be made of heavy steel plate and be very carefully welded. The design of a tank of this type is a matter which only the engineers of the refineries should attempt and hence be responsible for.

Simple Rectangular Tank

The first tank which will be described in this lesson will be a simple rectangular tank to contain five hundred gallons of water. Suppose that this tank was to be open at the upper end, or top, and could not be more than three feet high, and that the water level was to be three inches below the top edge. If the welder were told to make a tank, conforming to these requirements, the questions which would confront him at once would be: How large must this tank be made? What will be the thickness of metal required? How shall the tank be welded? This is a very simple example of a problem which may require an answer by any welder at any time.

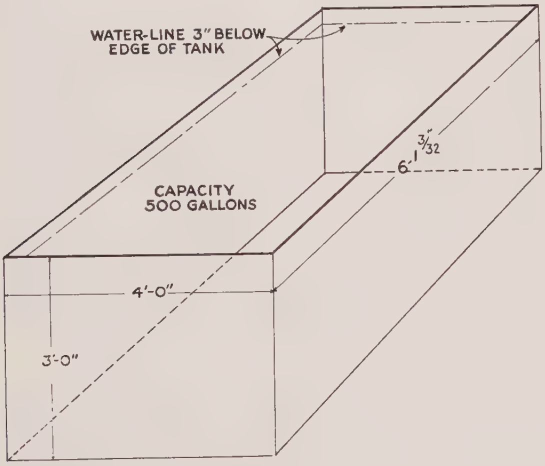


Figure 1—Sketch Showing Assembled View of a Simple Box-like Tank, Open at the Top and Welded as Described in the Text.

One gallon equals 0.134 cubic feet. Five hundred gallons would, therefore, equal five hundred times 0.134 cubic feet, or sixty-seven cubic feet. The water volume within the tank would, therefore, be sixty-seven cubic feet. It is specified that the tank be three feet in depth and that the water be three inches below the top edge. Therefore, the depth of the water would be two feet and nine inches, which is equal to 2.75 feet. This divided into sixty-seven cubic feet gives 24.36 square feet, which would be the area of the bottom of the tank. If the tank were made four feet wide, it would then have to be six feet, one and three-thirty-seconds inches long to give this area. In other words, 24.36 square feet divided by four linear feet gives 6.09 linear feet, which is equal to six feet, one and three-thirty-seconds inches.

The size of the tank, which is illustrated in Figure 1, has now been determined to be three feet in height, four feet in width and six feet, one and three-thirty-seconds inches in length. When filled to within three inches of the top, it will contain 500 gallons of water. These dimensions are, of course, inside dimensions. The next thing to determine is the thickness of the metal which will be required to hold this weight of water without buckling or bending out of shape, or breaking the seam. The weight of a cubic foot of water is equal to approximately sixty-two and one-quarter pounds. Therefore, the sixty-seven cubic feet of water contained in the tank would weigh 4170.75 pounds. The area of the base of the tank is 24.36 square feet, and the total weight 4171 pounds. Therefore, the weight per square foot may be assumed at 171 pounds, or the weight per square inch, 1.2 pounds.

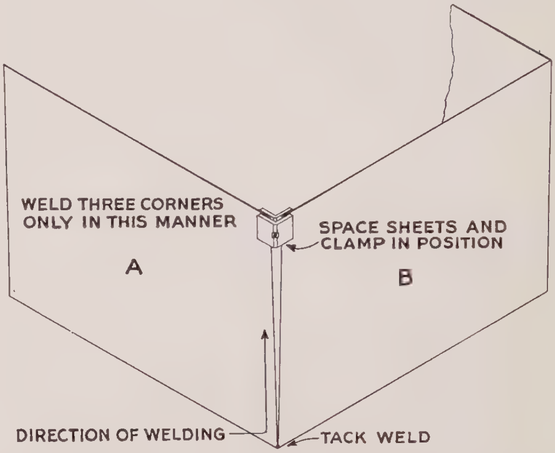

WELD THREE CORNERS ONLY IN THIS MANNER
A
SPACE SHEETS AND CLAMP IN POSITION
B
DIRECTION OF WELDING
TACK WELD

Figure 2—The First Seam to be Welded should be Tack Welded at the Bottom, Spread One-Quarter Inch to the Foot and Held in Position at the Top With an Angle Iron Clamp. Welding Should be Started at the Bottom of the Seam and Progress Vertically Upward to the Top.

If this tank is to be supported clear across the bottom upon a secure foundation, which is contemplated in this example, it will be realized that the weight of the water is not a serious consideration and that the thickness of metal which should be selected is that which will offer the least difficulty in welding and yet be stiff enough to hold the water without bending out the sides. No. 12 gauge steel, which is seven-sixty-fourths inches in thickness, would be satisfactory steel for this purpose. If this were used, it would be necessary to put around the top of the tank an angle iron frame made of one and one-half inch by one-eighth inch, equal leg, angle iron, which is the lightest standard section of this size, weighing one and three-tenths pounds per linear foot.

Of course, the thickness of the metal and the size of the angle iron usually would depend upon the material available in the shop, because such tanks are usually made of material which is scrap for other purposes. If lighter steel were used, it would be necessary to make another angle iron frame horizontally around the tank half way between the top and the bottom. In this event No. 16 gauge steel might be used. It is not the intention in this lesson to describe the welding of the angle iron frame, because that has already been done in other lessons, but to confine the description entirely to the making of the box-like tank.

Taking Care of Expansion

In Figure 1 the tank is shown assembled, giving the dimensions and the water capacity. If the steel available were of suitable size, it would, of course, be possible to make this tank by bending some of the corners. It has not been contemplated here that any of the corners should be bent, and it is assumed that the material available is too small for this purpose.

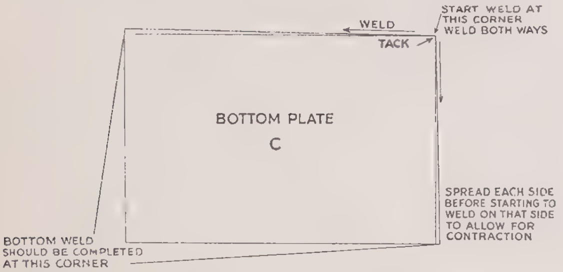

START WELD AT THIS CORNER WELD BOTH WAYS
WELD
TACK
BOTTOM PLATE
C
SPREAD EACH SIDE BEFORE STARTING TO WELD ON THAT SIDE TO ALLOW FOR CONTRACTION
BOTTOM WELD SHOULD BE COMPLETED AT THIS CORNER

Figure 3—The Bottom Plate Should be Welded in Position With Each of the Side Plates Spread, as heretofore Described, to Avoid Buckling. Spreading the Seam in this Manner Compensates for Expansion and Subsequent Contraction and thus Prevents the Buckling of the Steel Sheets.

The two end sheets should therefore, be cut upon shears if available, four feet long and three feet wide, and the two side sheets six feet one and three-thirty-seconds inches in length and three feet in width. The bottom sheet should be six feet one and three-thirty-seconds inches in length and four feet in width. In Figure 2 the method of welding the first corner is shown. A very convenient clamp for work of this kind consists of two short pieces of angle iron with the corner of the inner angle rounded so that it will fit close to the outer piece of angle iron. A hole is drilled completely through both pieces of angle iron and a bolt inserted through the hole. This is a very simple clamp which can be made by any welder and is illustrated in the upper part of Figure 2.

The sheets, A and B, should be spread a distance of approximately one-quarter inch per foot of length of seam when they are set at right angles on the welding table, or some other convenient support. A tack weld should then be made at the bottom of the seam, as indicated in Figure 2. Welding should start at the bottom and progress vertically upward to the top. The clamp should be loosened as the weld progresses, so that the two sheets will just come together when the puddle approaches the end of the seam.

In this manner the other two corners should be welded, but the fourth corner should be left open until after the bottom has been welded in place. Welding of the bottom plate, C, is indicated in Figure 3. When the three corners of the side plates have been welded, the bottom plate, C, should be placed in position with the tank upside down and the plate, C, supported upon suitable supports at its proper level. A tack weld should be made at the upper right-hand corner, Figure 3, and each side should be spread one-quarter inch to the foot, as shown. Welding should start at the tack welded corner in each instance and proceed along the spread seam to the next corner. All bottom welds should be completed before the corner weld, G-F, is attempted.

After the bottom has been completely welded, the tank should be turned right side up and the weld, between the plates, D and E, Figure 4, started at G and continued upward to F, after the seam has been spread approximately three-quarter inches at F. In this way all of the seams will be welded as open seams and no difficulty should be encountered with buckling.

When the tank has been welded and the angle iron frame has been completed, the frame can be slipped over the top and tack welded at several points to hold it in position.

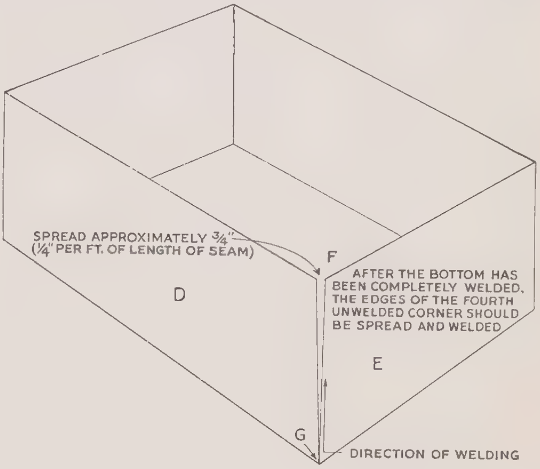

SPREAD APPROXIMATELY ¾"
(¼" PER FT. OF LENGTH OF SEAM)
F
D
AFTER THE BOTTOM HAS BEEN COMPLETELY WELDED, THE EDGES OF THE FOURTH UNWELDED CORNER SHOULD BE SPREAD AND WELDED
E
G
DIRECTION OF WELDING

Figure 4--The Last Seam to be Welded is Shown at G-F. This Seam also Is Spread Three-Quarters of an Inch and Welded Vertically, Starting at the Bottom, G, and Continuing Upward to the Top F.

Determining the Thickness of Steel to be Used for Pressure Tanks

There has been a great deal of discussion among engineers about the strength of a welded joint. Ordinarily tanks are made of open hearth steel and Specification S-I of the boiler code gives the following analysis:

Carbon	0.25%	for plates ¾" and under in thickness
Carbon	0.30%	for plates over ¾" in thickness
Manganese	0.80%	maximum
Phosphorus	0.035%	maximum for basic open hearth
Sulphur	0.04%	maximum for basic open hearth

There are other specifications covering higher grades of steel, but the carbon content is generally limited to 0.35% in order to avoid too much complication of assembly by welding. The tensile strength of steel given in Specification S-I is 55,000 to 65,000 pounds per square inch.

For figuring the dimensions, thickness of steel and pressures for tanks in this lesson the tensile strength of steel has been assumed to be 50,000 pounds per square inch.

The boiler code divides pressure tanks into three classifications constructed respectively in accordance with Paragraphs U-68, U-69 and U-70 and known by these designations. In general U-68 vessels are designed and constructed under very rigid requirements and are not restricted in their use.

U-69 vessels are built under slightly less rigid conditions and are therefore limited to 400 pounds pressure and 700 degrees temperature, as the maximum pressure and temperature at which they may be used.

U-70 vessels are constructed under still less rigid conditions and are limited to maximum pressures and temperatures of 200 pounds and 250 degrees respectively.

The rules require a good deal of study to thoroughly comprehend them and set forth in detail formulas for figuring the thickness of the steel to be used for given pressures and the strengths at which a welded joint may be figured when various grades of steel are used. The rules also give in detail the tests which are required and those which a welder must successfully pass in order to weld on this class of work.

When steel of the S-I specification is used and tanks are constructed in accordance with Paragraph U-70 the maximum thickness is ⅝ inch. Double welded butt joints for all joints are figured at 8,000 pounds per square inch, single welded butt joints at 6,500 pounds and when the material is less than 3/16 inch in thickness at 5,600 pounds.

The example given in Figure 5 is a tank which is not subject to code requirements and the figure 8,000 pounds is used in the calculations given. If this tank were for air, and therefore not exempt from the code, the formula would give a working pressure of only 50 pounds.

It is believed that the strength of a welded seam may be safely taken at 8,000 pounds per square inch. This is based on a breaking strength of the steel plate of 50,000 pounds and a factor of safety of six and one-quarter. A factor of safety is merely an allowance made above the actual breaking strength to provide for any defects, corrosion, or other causes for weakness in the steel, or the joint. The tank shown in Figure 5 would have to be protected in some way against corrosion.

Formulas for Figuring Thickness of Plate

Formulas for figuring the allowable safe pressure within a tank, when the thickness of the plate is given; or the thickness of the plate, when the pressure is given; are discussed in the following paragraphs. These are similar to the rules in Paragraph U-20 of the boiler code, but are expressed in a slightly different manner.

It is assumed that:

T=the thickness of the tank plates at the weakest place in inches.

P=the maximum allowable working pressure in pounds per square inch.

S=the strength of the welded seam, with an allowance or factor of safety of six and one-quarter=8,000 pounds per square inch of weld section.

R=the inside radius of the weakest part of the tank in inches.

Ordinarily, the weakest part of a tank is the longitudinal seam at the center of the tank. The formula for determining the thickness of the plates is:

$$T=\frac{P \times R}{S}$$

This formula is used when the pressure is known. When the thickness of the plates is known and the pressure is unknown, this formula becomes:

$$P=\frac{S \times T}{R}$$

As an example, suppose the tank in Figure 5 is taken. This tank is three feet six inches in outside diameter, and the thickness of the wall plate is three-sixteenths inches. The inside diameter of the tank is, therefore, three feet five and five-eighths inches, or expressed decimally in inches 41.63. The radius, or R, of this tank is 20.82 inches.

The thickness of the tank plates, T, is equal to three-sixteenths of an inch, or .188. The strength of the welded seam, S, is taken at 8,000 pounds per square inch. The formula

$P=\frac{S \times T}{R}$, therefore, reads $P=\frac{8000 \times .188}{20.82}$

P is equal to seventy-two pounds, and this is the maximum allowable working pressure which may be used in the tank. If the boiler code were strictly adhered to, this pressure would be even less, as is evident, but this pressure may be assumed to be the safe working pressure within a tank of this kind when properly welded.

These figures do not take the weight of the water in the tank into consideration. The depth of the water at the center of the tank cannot be greater, when the tank is full, than 41.63 inches. A cubic inch of water weighs 0.036 pounds, or a column of water 41.63 inches in height and covering one square inch of bottom surface exerts a pressure on the bottom of 41.63 x 0.036 pounds or approximately one and one-half pounds.

It is assumed in this instance that the tank is supported on a suitable foundation along its entire length. If therefore an allowance of two pounds is made for the weight of the water, the safe working water pressure would be seventy pounds per square inch.

Welding a 600 Gallon Tank for a Working Water Pressure of Seventy Pounds Per Square Inch

Figure 5 illustrates a tank designed to hold 600 gallons of water under a pressure of seventy pounds per square inch. The length of the straight portion of the tank is eight feet, made up of two four foot wide by eleven foot long, open hearth steel plates, bevelled to an included angle of ninety degrees, as shown at E. It will be noted that the four foot ends of the steel

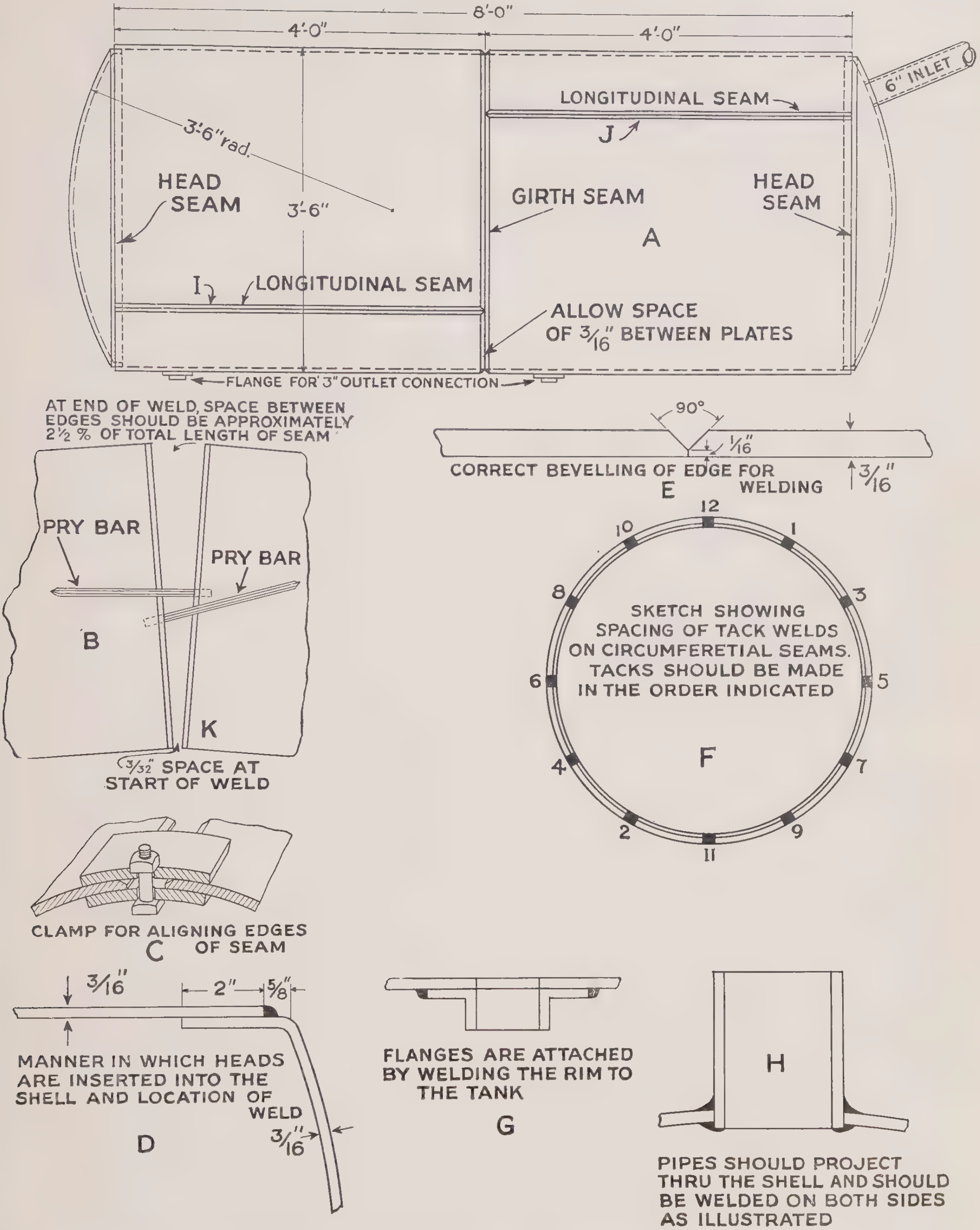

8'-0"
4'-0"
4'-0"
6" INLET
LONGITUDINAL SEAM
J
3'-6" rad.
HEAD SEAM
3'-6"
GIRTH SEAM
HEAD SEAM
A
I
LONGITUDINAL SEAM
ALLOW SPACE OF 3/16" BETWEEN PLATES
FLANGE FOR 3" OUTLET CONNECTION
AT END OF WELD, SPACE BETWEEN EDGES SHOULD BE APPROXIMATELY 2½ % OF TOTAL LENGTH OF SEAM
90°
1/16"
CORRECT BEVELLING OF EDGE FOR WELDING
3/16"
E
PRY BAR
PRY BAR
B
K
3/32" SPACE AT START OF WELD
12
1
10
3
8
SKETCH SHOWING SPACING OF TACK WELDS ON CIRCUMFERETIAL SEAMS. TACKS SHOULD BE MADE IN THE ORDER INDICATED
6
5
F
4
7
2
9
11
CLAMP FOR ALIGNING EDGES OF SEAM
C
3/16"
2"
5/8"
MANNER IN WHICH HEADS ARE INSERTED INTO THE SHELL AND LOCATION OF WELD
3/16"
D
FLANGES ARE ATTACHED BY WELDING THE RIM TO THE TANK
G
H
PIPES SHOULD PROJECT THRU THE SHELL AND SHOULD BE WELDED ON BOTH SIDES AS ILLUSTRATED

Figure 5—Sketches Illustrating the Design and Construction of a 600 Gallon Cylindrical Tank. This Tank has been Designed for a Working Pressure of Seventy Pounds Per Square Inch to Hold Water Only for a Domestic Water Supply System.

plates are bevelled and also one of the sides, but the other side is left square. This is clearly indicated in the Sketch A, Figure 5. The two lengths are rolled to an outside diameter of three feet six inches, when the longitudinal seams, I and J, are ready to be welded.

These seams are spread, as shown at B, Figure 5, allowing a space of three-thirty-seconds of an inch at the beginning of the weld, and spacing the far end of the seam two and one-half per cent of the total length, which is approximately equivalent to one-quarter inch per foot.

Welding the Longitudinal Seams

The near end of the seam may be welded at K and a clamp, similar to that shown at C, used at the opposite end of the seam.

If any difficulty is encountered, as the seam is welded, by a tendency of the plate to warp or buckle out of its plane, two pry bars may be used, one inserted over the edge of one sheet and under the other and the other likewise inserted, but in the opposite direction. A helper using these two pry bars will be able to keep the sheets in proper alignment, so that buckling will be reduced to a minimum. Ordinarily, however, with a clamp, such as that shown in Sketch C, there should be no difficulty caused by buckling. If desired, several of these clamps may be used, depending entirely upon the length of the seam. In this manner, both the longitudinal seams, I and J, can be welded through to the end and when the puddle approaches the end, the two plates should come in contact.

Welding the Girth Seam

When the longitudinal seams have been welded, the two sections of the tank should be placed together on supporting rollers so that they may be easily rolled and tack welded, leaving a space between the ends of the two cylinders equal to approximately three-sixteenths of an inch. Tack welds may be made approximately eleven inches apart, as shown at F, Figure 5. These tack welds should be made in the numerical order indicated at F, alternating 180 degrees apart. For instance, tack weld No. 1 is first made and then No. 2 directly opposite No. 1, then back to No. 3 and across to No. 4, etc. In this way the heat of the weld will be spread clear around the circumference of the tank and will not be localized to any great extent. The result will be better alignment of the two cylinders.

Welding of the girth seam is accomplished by beginning the weld at the top of the seam at any tack weld, and maintaining the puddle always at the top, rotating the two cylindrical shells as the puddle is advanced. This is the most convenient manner in which this weld can be made, and little difficulty will be encountered with expansion, because of the space left between the shells and the frequent tack welds. In every instance the tack weld should be again thoroughly fused and when the weld is completed clear around the circumference and meets the point of beginning, the previously made welds should be reheated for a distance of approximately two and one-half inches beyond the junction point.

Welding the Head Seams

The flanged and dished heads should be driven into each end of the tank, after the inlet pipe has been welded into the right hand head, as indicated at H. The pipe should project through the shell, as shown and should be welded from both sides of the head. The heads should be tack welded, as described for the girth seams, and welded by rotating in similar manner. Flanges attached to the shell for the outlet connections should be welded, as indicated at G.

Boiler Code Permits Welding Air Tanks Only When Welding Follows Standard Practice

The tank shown in Figure 5 is designed for a water pressure not exceeding seventy pounds for a domestic water supply system. While the boiler construction code is referred to with reference to the thickness of the shell and the pressure allowed, it should be borne in mind that the boiler code distinctly states that fusion welding upon air containers is permitted only when these containers are fabricated in accordance with standard rules covering the procedure and methods of welding given in the code.

While the code seems to provide rather drastic limitations to the construction of air containers and to place the value of a weld in steel of the thickness shown in Figure 5 rather low, it must be remembered that corrosion and other deterioration during service is a factor which must be considered.

Furthermore the boiler code committee, in recommending these rules, has taken into consideration the human element in the making of welds and has endeavored to safeguard the public, because of the possibility of an air tank being welded by an unskilled welder and becoming a hazard to property, as well as to life.

While the figures might show that a tank, such as that illustrated in Figure 5, has ample strength when new, it might be better engineering practice to increase the thickness several gauge numbers to care for possible internal corrosion during its service life.

It is known by the welding industry that welds properly made are much stronger than is generally realized and that there is no reason to believe that with proper inspection, similar to the inspection recommended by the code, poor welding is any more likely to occur than poor workmanship on any other kind of a joint.

These facts, however, illustrate the importance of proper instruction in welding and the necessity for conscientious work and a thorough understanding of the subject on the part of the welder.

Underwriters' Requirements for Storage Tanks

In the regulations of the National Board of Fire Underwriters for the installation of containers for storing and handling of inflammable liquids, there is a specification for general storage tanks. This specification requires that horizontal or vertical tanks, not exceeding 1,100 gallon capacity shall have the following minimum thickness of material:

For Storage Tanks Above Ground

Capacity In Gallons	Minimum Thickness of Material
1 to 60	18 Gauge
61 to 350	16 Gauge
351 to 560	14 Gauge
561 to 1100	12 Gauge

For horizontal tanks exceeding 1,100 gallons in capacity, and having a diameter not exceeding six feet, the rules require a thickness of steel of three-sixteenths inches. For tanks having a diameter over six feet and less than eleven and one-half feet, the rule specifies steel one-quarter inch in thickness. These specifications are all for storage tanks above ground. Under ground storage tanks are specified to be constructed of galvanized steel, open hearth steel or wrought iron of a minimum United States standard gauge, as given in the following table:

For Storage Tanks Underground

Capacity In Gallons	Gauge of Metal	Minimum Weight of Material Pounds Per Square Foot
1 to 285	16 Gauge	2.50
286 to 560	14 Gauge	3.125
561 to 1,100	12 Gauge	4.375
1,101 to 4,000	7 Gauge	7.50
4,001 to 12,000	¼"	10.00
12,001 to 20,000	5/16"	12.50
20,001 to 30,000	⅜"	15.00

The rules further require that open hearth steel or wrought iron thinner than No. 7 gauge shall be galvanized. There are, of course, other details of construction which must be adhered to, but these indicate the requirements particularly with reference to the thickness of metal.

Welding An Open Top Cylindrical Tank

An example of a welded cylindrical tank is illustrated in Figure 6. This tank is thirty-six inches in diameter and forty-eight inches in height. It is made of three-sixteenths inch steel. By referring to the table of circumferences and areas of circles, it will be noted that the circumference of a three foot circle is 9.42 feet. Reference to the table of inches in decimals of a foot will show that .42 of a foot is equal to five and one-sixteenth inches. The length of the shell of the tank must, therefore, be nine feet five and one-sixteenth inches, and the width of this plate four feet.

This plate should be rolled in cylindrical form; care should be taken that the edges at its ends are fully rounded and are not left flat. If care is not taken in this respect, there will be a flat surface along the longitudinal seam. The ends of this sheet should be beveled along this seam to forty-five degrees to make a single vee bevel.

Welding should begin at one end of the seam where a tack weld should be made and the other end spread one-quarter inch to the foot, or in this instance, one inch. This end of the seam should be clamped with a suitable clamp and the seam welded as usual.

The bottom of this tank is to be made of a circular plate cut with the cutting torch from a piece of square plate which is available. This is indicated in Figure 7. The most convenient way to make a circular cut is to use a circle cutting attachment for a cutting torch. The cutting attachment should be set to a diameter of eighteen inches between the center of the attachment and the center of the torch tip. A center punch mark should then be made in the plate so that it is exactly eighteen inches from each of two edges of the rectangular plate.

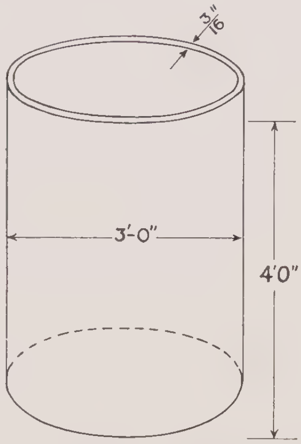


Figure 6—Sketch Showing a Cylindrical Tank Thirty-six Inches in Diameter and Forty-eight Inches in Height, Made of Three-Sixteenths Inch Steel.

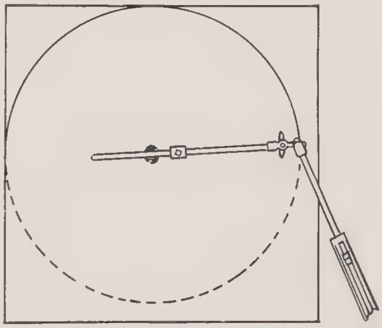


Figure 7—Sketch Showing the Method of Using a Circular Cutting Attachment for the Cutting Torch to Cut a True Circle for the Bottom of the Tank Shown in Figure 6.

When this is done the torch may be lighted, the center of the cutting attachment slipped into the center punch mark and the cut started from the edge of the plate. It should be continued in a circle around until it is completed. In this manner the cut may be started from the edge, which is easier than attempting to punch a hole through the plate with the torch cutting jet. The circular piece will be cut with as little waste of material as possible.

Thirty-six inches is the inside diameter of the rolled steel shell and, therefore, the bottom when cut in this manner would slip inside of the tank. This is done to avoid bevelling either the end of the tank or the bottom plate. The oxide caused by cutting should be cleaned away from the plate with a cold chisel and a hammer and the bottom should be supported in one end of the shell so that the lower surface of the bottom plate is just even with the upper edges of the shell. This can be done by putting a post exactly four feet in length in the center of the tank upon which the bottom should rest.

The bottom may then be tack welded in position. The tack welds are made first on one side of the bottom, then across to the opposite side, then to a point at an angle of ninety degrees from the line of the first two tacks and across to the opposite side. In this manner eight tack welds should be made in proper sequence, as heretofore described. The weld may then be started at one of the tack welds and continued half way around the circumference. The weld should then be started again at the point of beginning and continued around the opposite half until it is completed. There should be no difficulty in constructing a small tank of this kind, and a little practice will enable the welder to do an excellent job.

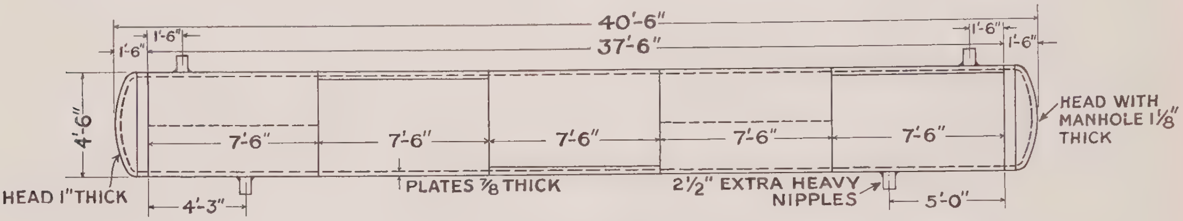


Figure 8—Sketch Showing Recommended Construction for a Large Tank Forty Feet Six Inches in Length and Four Feet Six Inches in Outside Diameter, Designed for a Pressure of 268 Pounds Per Square Inch.

Welding a Large Tank for Two Hundred and Sixty-Eight Pounds Pressure Per Square Inch

The welding of large tanks for pressures of more than two hundred and fifty pounds means entering a field of welding where there is relatively little precedent upon which to base engineering practice. It is thought desirable, however, that the welder should know how extensive experience has been in this class of construction work.

The Carbide and Carbon Chemicals Corporation at one of its plants in West Virginia has constructed a large number of tanks, welded by the oxy-acetylene process, some of which were the largest welded tanks for a pressure of three hundred pounds, which have been built. One of these was forty-three feet in extreme length and five feet in diameter. This tank was fully described in a very interesting paper presented by H. E. Rockefeller, an engineer for The Linde Air Products Company, before a joint meeting of the Metropolitan Section of the American Welding Society and the Machine Shop Practice Division of the American Society of Mechanical Engineers on January 7, 1927. The engineering practice both with reference to the design and the methods for welding this tank are believed to be the best which has so far been developed. The paper describing this work was a very complete and specific paper, giving details of both design and construction.

In Figure 8 a tank is shown having an overall length of forty feet, six inches, an outside diameter of four feet, six inches, and designed for a pressure of two hundred and sixty-eight pounds. The principles of design and construction are similar to those laid down in the previously mentioned paper. Suppose the formula to determine the thickness of the plate, given heretofore in this lesson, is applied in this instance. The formula reads: $T = \frac{P \times R}{S}$. To be exact T is equal to 267.94 pounds per square inch. R is equal to 26.125 inches and S is equal to 8000 pounds per square inch. Therefore, T is equal to $\frac{267.94 \times 26.125}{8000}$, which is equal to 0.875 inches, or seven-eighths of an inch. The plates of all of the cylindrical sections are, therefore, made seven-eighths of an inch in thickness.

It was shown in the paper described, however, that the heads of the average tank were points of weakness, particularly if a manhole was constructed in one end of the tank. For this reason, the head in which there is no manhole has been increased in thickness to one inch and that in which there is a manhole to one and one-eighth inch steel.

Welding the Longitudinal Seams

The seven foot, six inch sections of plate should be rolled to the correct diameter, after edges have been double veed, as shown at A, Figure 9. The end of the plate should be bent slightly, before being rolled, to overcome the tendency of the rolls to leave a flat spot in the plate along the seam. The longitudinal seam of each section should be spaced one-eighth of an inch apart at the end of the seam near the welder and spread one and seven-eighths inches apart, or one-quarter inch per linear foot of length of seam, at the far end. The far end of the seam should be clamped and wedges used to maintain a constant spacing of about one-sixteenth of an inch immediately ahead of the puddle. This can be readily accomplished by proper manipulation of the clamps and wedges. Welding should be started at the near end and continued clear through to the opposite end of the seam.

It is good practice to tilt the rolls, or supports of the shell, to an angle of approximately fifteen degrees upward in the direction of welding. This will assist in maintaining a larger puddle and in the building up of the necessary reinforcement. The welding which has been described for this seam, it should be understood, is in the outside vee. All of the longitudinal seams should be double veed, and hence after welding the outside vee, it would be necessary to complete welding of the longitudinal seam by welding on the inside of the tank.

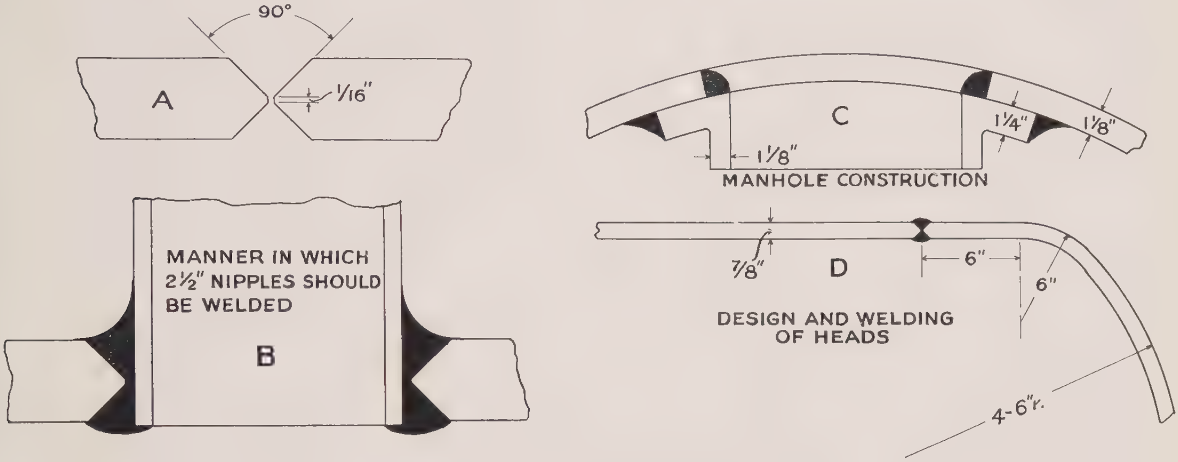

90°
1/16"
A
MANNER IN WHICH 2½" NIPPLES SHOULD BE WELDED
B
C
1⅛"
1¼"
1⅛"
MANHOLE CONSTRUCTION
7/8"
D
6"
6"
DESIGN AND WELDING OF HEADS
4-6"r.

Figure 9—Details of Design of the Tank Shown in Figure 8. A, Indicates the Double Vee Bevel Required for All Seams. B, Shows the Welding of the Inlet and Outlet Nipples From Both the Outside and Inside of the Tank. C, Shows the Manhole Collar Construction also Arranged for Welding Both Inside and Outside of the Head. D, Indicates the Head Seam Double Vee Weld Located Well Away from the Short Radius Bend in the Head. It also Indicates a Longer Radius than is Often the Case in Forming Such Heads.

In welding heavy plates it will usually be necessary to preheat the outside of the seam, with an oil preheating torch, four or five inches ahead of the point of welding on the inside of the tank. This preheating offsets radiation of the heat away from the weld and enables the welder to maintain the puddle on the inside of the tank at a proper temperature. Air, supplied from the shop compressors, may be forced through the inside of the tank to keep it cool enough for the welder to work. When welding heavy plates, it may be necessary to anneal a seam of this kind by heating to a dull red heat, with oil preheating torches, the entire area along the seam for about one foot in width on each side of it. The seam should then be rolled into a bed of dry ashes, completely covered up and allowed to cool slowly. Such treatment prevents stresses from being locked up in the metal.

Welding the Girth Seams

Two cylindrical sections should be placed together on rolls and securely fastened with wedges, similar to those indicated in the sketch, Figure 10. The spacing between the edges of the double vee bevel should be one-half inch all the way around the seam. These wedge clamps should be inserted about six or eight inches apart around the circumference. The seam should then be tack welded at four points, at the top and the bottom and at each side. These four tack welds will maintain the alignment of the two cylindrical sections and the wedge clamps will greatly help in caring for expansion and subsequent contraction. The tack welds should be made by two welders, working at opposite points, and should be three or four inches in length. When the first two tack welds are made, the cylinders should be rolled through an angle of ninety degrees and the other two tack welds made. The principle is identical with that previously described for pipe welding.

The outer vee of the double seam should be welded first. This should be done at the top of the tank about ten or fifteen degrees off center so that the weld is continually being made uphill. The welder should sit in a fixed position and the tank be turned to suit his requirements. Beginning with one of the tack welds, two of the wedge clamps should be removed and as the weld progresses, other clamps should be taken out so that a space of approximately one-quarter inch is always maintained between the edges of the seam about one foot ahead of the puddle. To control the expansion of the steel, it sometimes may be necessary to weld close to one of the wedges and the vertical part of the wedge may thus become pinched in the seam. If this should occur, it then would be necessary to cut out this part of the clamp with the cutting torch. The essential feature of this method of welding is to prevent the seam, through the use of the wedges, from approaching too close immediately forward of the puddle.

The outer vee should be completely welded around the circumference in this manner. The inner vee should then be welded, using a preheating torch on the outside of the cylinder and immediately forward of the point where welding is being accomplished on the inside seam. The inside puddle should be maintained at an angle of about fifteen degrees off center, so that welding on the inside seam will also progress slightly uphill. The welder on the inside of the tank should maintain his position and the tank should be rolled to suit his requirements.

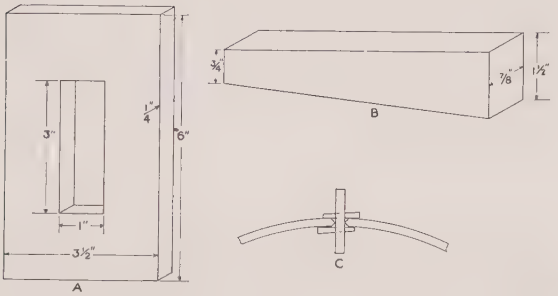


Figure 10—Sketches Showing Wedges Used to Counteract the Effect of Expansion and Contraction, Particularly During Welding of the Girth Seams.

The manner in which the extra heavy inlet and outlet nipples of this tank should be welded to the shell is shown at B, Figure 9, and the method for welding the manhole collar to the inside of the manhole end of the tank is shown at C. D indicates the location of the head seams and it will be noted that these are shown six inches away from the short bend in the head of the tank. This distance and the six inch radius of the short bend are both important, because such a design affords greater strength than would be the case if the weld were close up to a shorter radius bend at this point.

Welding the Head Seams

The head seams should be welded in identically the same manner as the other girth seams. The location of these seams is such that they do not present any problems which differ materially from those of girth seams. All of the recommendations which are made in connection with this tank are similar to those originally made by the Linde Air Products Company's engineers after their experience with the previously mentioned tank.

Table Converting Inches and Fractions of an Inch into Decimals of a Foot

In.	0	1/32	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	11/32	3/8	13/32	7/16	15/32	1/2	17/32	9/16	19/32	5/8	21/32	11/16	23/32	3/4	25/32	13/16	27/32	7/8	29/32	15/16	31/32
0	0	.002	.005	.007	.010	.013	.015	.018	.020	.023	.026	.028	.031	.033	.036	.039	.041	.044	.046	.049	.052	.054	.057	.059	.062	.065	.067	.070	.072	.075	.078	.080
1	.083	.085	.088	.091	.093	.096	.099	.101	.104	.106	.109	.112	.114	.117	.119	.122	.125	.127	.130	.132	.135	.138	.140	.143	.145	.148	.151	.153	.156	.158	.161	.164
2	.166	.169	.171	.174	.177	.179	.182	.184	.187	.190	.192	.195	.197	.200	.203	.205	.208	.210	.213	.216	.218	.221	.224	.226	.229	.231	.234	.237	.239	.242	.244	.247
3	.250	.252	.255	.257	.260	.263	.265	.268	.270	.273	.276	.278	.281	.283	.286	.289	.291	.294	.296	.299	.302	.304	.307	.309	.312	.315	.317	.320	.322	.325	.328	.330
4	.333	.335	.338	.341	.343	.346	.349	.351	.354	.356	.359	.362	.364	.367	.369	.372	.375	.377	.380	.382	.385	.388	.390	.393	.395	.398	.401	.403	.406	.408	.411	.414
5	.416	.419	.421	.424	.427	.429	.432	.434	.437	.440	.442	.445	.447	.450	.453	.455	.458	.460	.463	.466	.468	.471	.474	.476	.479	.481	.484	.487	.489	.492	.494	.497
6	.500	.502	.505	.507	.510	.513	.515	.518	.520	.523	.526	.528	.531	.533	.536	.539	.541	.544	.546	.549	.552	.554	.557	.559	.562	.565	.567	.570	.572	.575	.578	.580
7	.583	.585	.588	.591	.593	.596	.599	.601	.604	.606	.609	.612	.614	.617	.619	.622	.625	.627	.630	.632	.635	.638	.640	.643	.645	.648	.651	.653	.656	.658	.661	.664
8	.666	.669	.671	.674	.677	.679	.682	.684	.687	.690	.692	.695	.697	.700	.703	.705	.708	.710	.713	.716	.718	.721	.724	.726	.729	.731	.734	.737	.739	.742	.744	.747
9	.750	.752	.755	.757	.760	.763	.765	.768	.770	.773	.776	.778	.781	.783	.786	.789	.791	.794	.796	.799	.802	.804	.807	.809	.812	.815	.817	.820	.822	.825	.828	.830
10	.833	.835	.838	.841	.843	.846	.849	.851	.854	.856	.859	.862	.864	.867	.869	.872	.875	.877	.880	.882	.885	.888	.890	.893	.895	.898	.901	.903	.906	.908	.911	.914
11	.916	.919	.921	.924	.927	.929	.932	.934	.937	.940	.942	.945	.947	.950	.953	.955	.958	.960	.963	.966	.968	.971	.974	.976	.979	.981	.984	.987	.989	.992	.994	.997

Table Converting Gallons Into Cubic Feet

Gallons	Cubic Feet	Gallons	Cubic Feet	Gallons	Cubic Feet	Gallons	Cubic Feet
1	0.134	9	1.203	80	10.694	700	93.58
2	0.267	10	1.337	90	12.031	800	106.94
3	0.401	20	2.674	100	13.368	900	120.31
4	0.535	30	4.010	200	26.736	1000	133.68
5	0.668	40	5.347	300	40.10	2000	267.36
6	0.802	50	6.684	400	53.47	3000	401.04
7	0.936	60	8.021	500	66.84	4000	534.72
8	1.069	70	9.358	600	80.21	5000	668.40

Table Converting Cubic Feet Into Gallons

Cubic Feet	Gallons	Cubic Feet	Gallons	Cubic Feet	Gallons	Cubic Feet	Gallons
1	7.48	8	59.84	60	448.8	400	2992.2
2	14.96	9	67.32	70	523.6	500	3740.3
3	22.44	10	74.81	80	598.4	600	4488.3
4	29.92	20	149.61	90	673.2	700	5236.4
5	37.40	30	224.4	100	748.1	800	5984.4
6	44.88	40	299.2	200	1496.1	900	6732.5
7	52.36	50	374.0	300	2244.2	1000	7480.5

Capacities of Cylindrical Tanks in Gallons

Diam. in Feet	Length of Tank in Feet														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	5.88	11.76	17.64	23.52	29.40	35.28	41.16	47.04	52.92	58.80	64.68	70.56	76.44	82.32	88.20
2	23.50	47.00	70.50	94.00	117.50	141.00	164.50	188.00	211.50	235.00	258.50	282.00	305.50	329.00	352.50
3	52.88	105.76	158.64	211.52	264.40	317.28	370.16	423.04	475.92	528.80	581.68	634.56	687.44	740.32	793.20
4	94.00	188.00	282.00	376.00	470.00	564.00	658.00	752.00	846.00	940.00	1034.00	1128.00	1222.00	1316.00	1410.00
5	145.00	290.00	435.00	580.00	725.00	870.00	1015.00	1160.00	1305.00	1450.00	1595.00	1740.00	1885.00	2030.00	2175.00
6	211.50	423.00	634.50	846.00	1057.50	1269.00	1480.50	1692.00	1903.50	2115.00	2326.50	2538.00	2749 50	2961.00	3172.50

Circumferences and Areas of Circles

Diameter		Circumference in Feet	Area in Square Feet	Diameter		Circumference in Feet	Area in Square Feet	Diameter		Circumference in Feet	Area in Square Feet
Feet —	Inches			Feet —	Inches			Feet —	Inches		
0	1	.2617	.0054	2	1	6.5449	3.4088	4	1	12.8281	13.0954
	2	.5235	.0218		2	6.8067	3.6870		2	13.0899	13.6353
	3	.7853	.0490		3	7.0685	3.9760		3	13.3517	14.1862
	4	1.0471	.0872		4	7.3303	4.2760		4	13.6135	14.7480
	5	1.3089	.1363		5	7.5921	4.5869		5	13.8753	15.3207
	6	1.5707	.1963		6	7.8539	4.9087		6	14.1371	15.9043
	7	1.8325	.2672		7	8.1157	5.2414		7	14.3989	16.4988
	8	2.0943	.3490		8	8.3775	5.5850		8	14.6607	17.1042
	9	2.3561	.4417		9	8.6393	5.9395		9	14.9225	17.7205
	10	2.6179	.5454		10	8.9011	6.3050		10	15.1843	18.3477
	11	2.8797	.6599		11	9.1629	6.6813		11	15.4461	18.9859
1	0	3.1415	.7853	3	0	9.4247	7.0685	5	0	15.7079	19.6349
	1	3.4033	.9217		1	9.6865	7.4667		1	15.9697	20.2949
	2	3.6651	1.0690		2	9.9483	7.8758		2	16.2315	20.9657
	3	3.9269	1.2271		3	10.2101	8.2957		3	16.4933	21.6475
	4	4.1887	1.3962		4	10.4719	8.7266		4	16.7551	22.3402
	5	4.4505	1.5762		5	10.7337	9.1684		5	17.0169	23.0438
	6	4.7123	1.7671		6	10.9955	9.6211		6	17.2787	23.7582
	7	4.9741	1.9689		7	11.2573	10.0847		7	17.5405	24.4837
	8	5.2359	2.1816		8	11.5191	10.5592		8	17.8023	25.2200
	9	5.4977	2.4052		9	11.7809	11.0446		9	18.0641	25.9672
	10	5.7595	2.6398		10	12.0427	11.5409		10	18.3259	26.7253
	11	6.0213	2.8852		11	12.3045	12.0482		11	18.5877	27.4943
2	0	6.2831	3.1415	4	0	12.5663	12.5663	6	0	18.8495	28.2743

U. S. Standard Sheet Metal Gauge

No. of Gauge	Thickness, Inches Fraction	Decimal	Weight per Square Foot Iron Based on Weight of 480 lbs. per cubic ft.	Steel Based on Weight of 489.6 lbs. per cubic ft.	No. of Gauge	Thickness, Inches Fraction	Decimal	Weight per Square Foot Iron Based on Weight of 480 lbs. per cubic ft.	Steel Based on Weight of 489.6 lbs. per cubic ft.
7-0	½	.5	20.00	20.4	17		.0563	2.25	2.295
6-0	15/32	.4688	18.75	19.125	18		.05	2.	2.04
5-0	7/16	.4375	17.50	17.85	19		.0438	1.75	1.785
4-0	13/32	.4063	16.25	16.575	20		.0375	1.50	1.53
3-0	⅜	.375	15.00	15.30	21		.0344	1.375	1.4025
2-0	11/32	.3438	13.75	14.025	22	1/32	.0313	1.25	1.275
0	5/16	.3125	12.50	12.75	23		.0281	1.125	1.1475
1	9/32	.2813	11.25	11.475	24		.025	1.	1.02
2	17/64	.2656	10.625	10.8375	25		.0219	.875	.8925
3	¼	.25	10.	10.2	26		.0188	.75	.765
4	15/64	.2344	9.375	9.5625	27		.0172	.6875	.7012
5	7/32	.2188	8.75	8.925	28	1/64	.0156	.625	.6375
6	13/64	.2031	8.125	8.2875	29		.0141	.5625	.5737
7	3/16	.1875	7.5	7.65	30		.0125	.5	.51
8	11/64	.1719	6.875	7.0125	31		.0109	.4375	.4462
9	5/32	.1563	6.25	6.375	32		.0102	.40625	.4143
10	9/64	.1406	5.625	5.7375	33		.0094	.375	.3825
11	⅛	.125	5.	5.1	34		.0086	.34375	.3506
12	7/64	.1094	4.375	4.4625	35		.0078	.3125	.3187
13	3/32	.0938	3.75	3.825	36		.0070	.28125	.2868
14	5/64	.0781	3.125	3.1875	37		.0066	.265625	.2709
15		.0703	2.8125	2.8687	38		.0063	.25	.255
16	1/16	.0625	2.5	2.55					

Job Sheet No. 8

Welding Long Seams

The work required in this lesson consists of making welds between pieces of 14 gauge sheet steel three inches wide and thirty-six inches long. This material should be cut on shears, if available, to the above size.

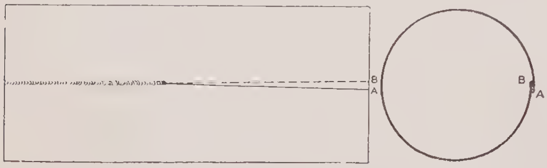


Figure 11—Sketch Showing a Cylindrical Shell Partly Welded Without Making Proper Allowance for Expansion. Note that when the Weld has been Made Along Part of the Seam the Edges, A and B, will Overlap, Making It Almost Impossible to Complete the Weld.

The student should first of all select the apparatus to be used for this thickness of metal, and see that it is properly connected and in good working order.

Select two pieces of 14 gauge sheet steel three inches wide, thirty-six inches long and place them edge to edge upon some fire brick. The two pieces should now be tack welded at one end and the other end left free. No space should be left between the edges of the pieces. Start welding the seam.

As the weld progresses, note how the edges of the seam ahead of the weld pull together. This contraction increases as the welding continues until finally one of the edges overlaps the other making a butt weld between the two edges impossible. This condition is illustrated by the two sketches in Figure 11. Here the edge, A, has entirely covered the other edge, B. This job is given so that the necessity of spacing the edge, using clamps, and other means of controlling expansion and contraction, will be impressed upon the student.

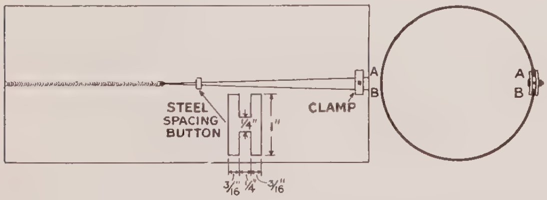


Figure 12—Sketch Showing a Cylindrical Shell Properly Spaced to Allow for Expansion and Contraction. A Steel Spacing Button, Shaped Like the Letter H, Is Shown in Detail, which, When Moved Ahead of the Weld as It Progresses, Will Help to Keep the Plates Properly Separated and in Line. The Edges, A and B, Should Be Separated One-quarter Inch Per Foot of Length of Seam and Held in Place with the Clamp Until the Weld Is Started. The Clamp Should Then Be Loosened and the Spacing Button Moved as the Weld Progresses.

Job number two consists of making the same type of weld, but in the correct manner. Two more pieces of steel should be placed edge to edge upon the welding table, so the front edges are about three thirty-seconds inches apart and the far ends separated one-quarter inch for each foot of length of seam. In this case, the distance would be three-quarters of an inch. The two pieces should now be tack welded together at the front end, a spacing button, as illustrated in Figure 12, slipped between the edges, and the far end fastened securely in a clamp. After the clamp has been tightened in place, slide the spacing button as far as possible to the narrow end of the crack. The purpose of this button is to keep the edges of the plates forced apart.

Commence welding at the tack and weld toward the button. As the weld progresses, the spacing button will hold the edges apart. The distance between the edges should be controlled by sliding the button away from the weld from time to time so that the edges, at the puddle, are approximately one-sixteenth inch apart. In this way the overlapping of the edges is prevented.

Questions:

1. What is the boiler construction code?
2. What pressure is the maximum pressure that should be allowed in a welded tank six feet long, thirty inches in diameter and made of plates three-eighths of an inch thick?
3. It is desired to build a rectangular, open top storage tank to hold seven hundred and fifty gallons of water. The tank must be seven feet six inches long and the water-line one inch below the top of the tank. Give full details as to size and thickness of the tank and material.
4. Does the boiler construction code permit the tank described in question number two to be used for air under a pressure of 175 pounds per square inch?
5. Make a rough sketch, showing dimensions of a cylindrical tank ten feet long with a capacity of one thousand gallons under pressure of one hundred and twenty-five pounds per square inch.

Lesson No. 9

Miscellaneous Steel Welding Jobs About a Job Shop

AUTOMOBILE parts are made of carbon and alloy steels, particularly adapted for the service which the part must render. These steels consist of carbon steels, nickel steels, nickel chromium steels, chromium steels, chromium vanadium steels, chromium tungsten steels and silico manganese steels. All of these steels, with various percentages of the elements, have their particular uses in the construction of an automobile. For this reason the welding of automobile parts is a matter requiring more careful consideration than would be the case if all of the steels were simple low carbon steels. Furthermore, almost all of the parts made from these steels are heat treated, so that each part will have the correct temper, hardness, strength and toughness required of that particular part.

When such steel is melted with the torch, these characteristics, of course, to a very large extent, disappear and the weld becomes cast steel which is strong enough for many purposes, but not nearly strong enough in other instances. For example, a steering knuckle of an automobile is a part subjected to tremendous strain and its ability to withstand this severe service is dependent upon the very high grade of special steel of which it is made and the heat treatment of this steel. If the steering knuckle breaks, the safety of the car and its occupants is instantly jeopardized. It would be almost impossible to reinforce a steering knuckle as other parts of the car may be reinforced, and therefore, a welded knuckle must of necessity be considerably weaker than the original part.

For this reason it is conservative to say that steering knuckles should not be welded. The welder in so doing has no positive means for determining the strength of the completed job and he would be assuming too much risk, particularly where life itself may be sacrificed if a break occurred. The welding of automobile parts should be confined to those breaks which can be repaired without difficulty and where the weld can be properly reinforced to make it as strong or stronger than the original part.

Welding Broken Automobile Frames

Automobile frames are usually made of pressed steel channel sections. They are made of carbon steel with a carbon content of 0.20 to 0.25 per cent carbon, or of nickel chrome steel with a carbon content of 0.25 to 0.35 per cent. The frame consists of side members, extending the length of the car, and two or more cross members attached to the side members either by welding or hot riveting. The frame is made narrow in front to provide space for the front wheels in steering and sometimes has a rise at the rear to give greater clearance over the rear axle. The particular design of the frame, however, is dependent upon whether it is intended for passenger vehicles or for trucks and also upon the make of the car or truck.

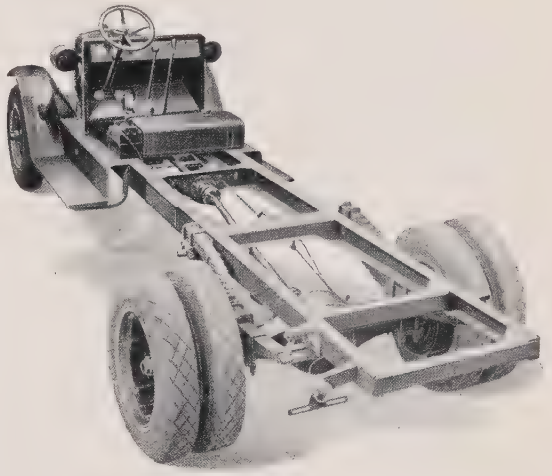


Figure 1—Illustration of a Truck Chassis Upon the Side of the Frame of Which a Typical Reinforced Repair Has Been Drawn.

Automobile frames are so treated during manufacture that the steel is strong, resilient and resists shock as much as possible. At the same time the frame is so designed that it is as light as it can be made and yet have sufficient strength to stand up under the severe conditions of service. When a frame breaks it is usually due to an overload, or to some unusually severe blow or impact, which strains the metal beyond its strength. The mechanical and heat treatment of the frame is such during manufacture that the steel has been refined and worked until it is stronger than it was in its original condition. If it is an alloy steel instead of a carbon steel, the various elements which have been added to the steel increase its strength, ductility and toughness.

When a weld is made in a frame and the puddle of metal is heated hot and quite liquid, chemical reactions occur in the steel which reduce in quantity its various elements, including the carbon, and chemically change the characteristics of the steel so that the strength, ductility and toughness caused by its original mechanical treatment are lost. The changes which have taken place when the metal was very hot have altered the composition of the steel and the size of its grains so that it cannot be expected to have its original strength.

When the puddle of a weld is heated to a thin liquid, immediately adjacent the puddle the temperature of the steel is progressively reduced as the distance from the puddle increases. When steel is heated to a temperature somewhere between the colors, No. 5 and No. 6, Chart No. 6, Lesson No. 7, the grain of the steel is not seriously affected. No. 5 is a cherry or full red heat, indicating a temperature of approximately 1375 degrees Fahrenheit, while No. 6 is a bright red heat, the temperature being about 1550 degrees Fahrenheit. If heated up to this color no particular change occurs in the steel, but when the heat is raised to a white heat, about 2200 degrees, the grain of the metal increases in size and the metal remains coarse grained. When the grain of the metal has been coarsened in this manner, its strength has been decreased. When the weld cools down, the metal which has been heated to this point, that is, to a white heat, is not as strong as the refined steel which originally constituted the frame itself.

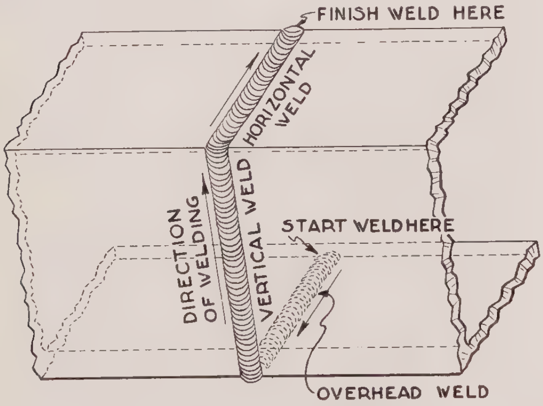


Figure 2—The Break in the Truck Frame Should First Be Welded. Reinforcement of the Weld Will Depend Upon the Location of the Reinforcement Plate and Interference with Other Parts. The Weld should be Reinforced, however, Either Inside or Outside of the Channel, Depending Upon Circumstances.

It is common practice in making a weld to build the weld section to a greater thickness than the metal adjacent to it. For this reason the weld is strong, perhaps as strong as the original metal, but there is a zone lying along side of the weld which has been heated to a white heat and is, therefore, changed in its characteristics. The result of this heat is decreased strength in this adjacent area.

The chemical and physical changes which take place in steel when it is heated constitute a very interesting subject. These changes are usually dealt with in such a technical manner that the average man has difficulty in understanding them and the results produced. There is a book published by the Frederick A. Stokes Co., New York City, which every welder should read and will find interesting. This book is entitled, "Non-Technical Chats on Iron and Steel," by LaVerne W. Spring. The book is written, as its name indicates, so that a student or welder can understand it and it gives much valuable information about iron and steel, its manufacture and its various characteristics.

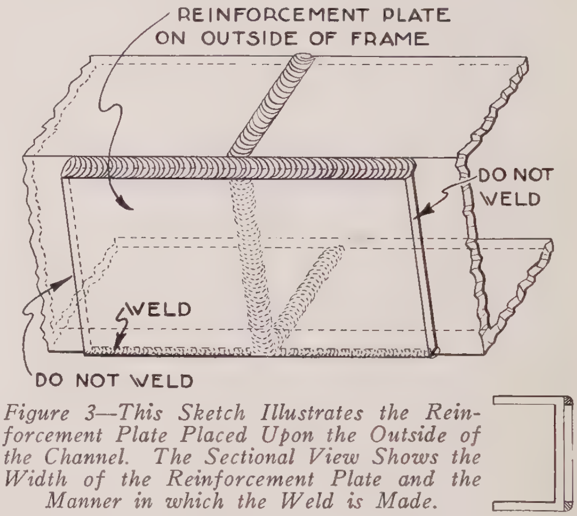


Figure 3—This Sketch Illustrates the Reinforcement Plate Placed Upon the Outside of the Channel. The Sectional View Shows the Width of the Reinforcement Plate and the Manner in which the Weld is Made.

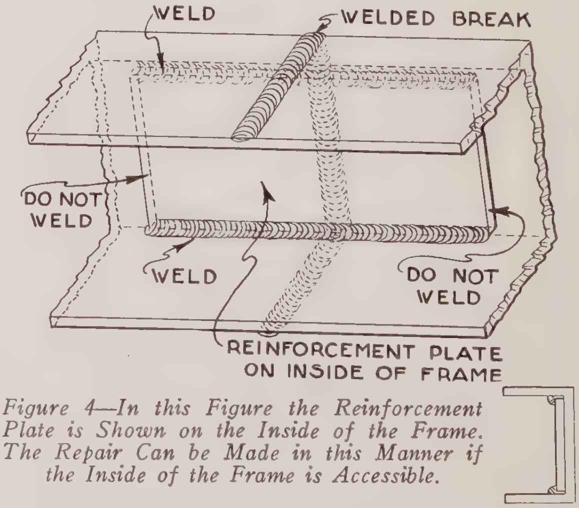


Figure 4—In this Figure the Reinforcement Plate is Shown on the Inside of the Frame. The Repair Can be Made in this Manner if the Inside of the Frame is Accessible.

From these remarks it will be noted that the hotter the steel is heated in the puddle in making a weld the more rapid and the greater are the chemical changes which take place. This severe heating is usually indicated by excessive sparking. It is, therefore, obvious in making a steel weld that the puddle should not be overheated. It should be thick and sluggish and no hotter or more liquid than necessary to fuse through to the bottom of the section. The heat of the puddle can be very easily controlled, which is one of the great advantages of the oxy-acetylene torch. It is only necessary to hold the torch a little further away from the metal, or to change the direction of the flame, to maintain the heat of the puddle at any desired temperature and thus control the consistency of the molten metal.

Control of the heat in this manner is particularly necessary in frame welding, because of the higher grade of steel used, and the necessity for having a joint, when the weld is completed, which will withstand the severe service which caused the original break to occur. From these remarks it is obvious that close beside a weld there is a part of the frame where the strength of the steel has been decreased by heating. If the frame is again overloaded, in a manner similar to the condition which caused the original break, it will be likely to break in this area, not through the weld itself, but closely adjacent to it.

In welding passenger car frames, a simple weld in the frame is usually sufficient, because a condition which causes a passenger car frame to break is usually abnormal and not likely to be repeated. Welding truck frames is altogether different. A truck frame usually breaks because of an overload and overloading is likely to be the rule rather than the exception. For this reason it is good practice to reinforce a weld in a truck frame with an additional reinforcement plate, either on the bottom, or on the inside, or the outside of the frame as may be convenient.

It is not always possible to get at the inside of a frame and, therefore, in many instances the reinforcement plate is welded to the outside or to the bottom, as the case may be. In Figure 1 a chassis of a well known truck is shown and the frame is clearly illustrated. This photograph will give a very fair idea of the manner in which frames are constructed. A typical weld has been drawn on the frame, made with an outside reinforcement plate.

A frame of the type indicated in Figure 1 is eight inches deep and one-quarter of an inch thick for a three and one-half ton truck and a five ton truck. For a two and one-half ton truck, the frame usually is seven inches in depth and one-quarter of an inch in thickness, and for a one ton truck six inches in depth and three-sixteenths inches in thickness.

A No. 4 tip should be used for the smaller frame and a No. 5 tip for the larger size. Three-sixteenths and one-quarter inch low carbon steel welding rods of the specification of the American Welding Society are usually the most satisfactory rods for the purpose, although nickel steel or a rod having a slightly higher carbon content than the low carbon rod just mentioned can be used.

As the carbon content of a welding rod increases, it flows with less freedom and requires more skill in the manipulation of both rod and torch. It is, therefore, believed that the average welder will make a better frame weld by using low carbon rod and heavily reinforcing the weld than if a welding rod of higher carbon content, or an alloy welding rod is used. The first step in making a weld of this type is to jack up the body, after removing the body bolts, in such manner that it will not interfere with welding. Wet asbestos and asbestos paper should be used to protect the body and the paint, wherever exposed, so that as little damage as possible will be done to it. The frame should then be jacked up into line in its proper position.

If the frame is three-sixteenths inches in thickness, it is not necessary to vee the edges prior to welding, as penetration may be easily secured without the vee. If the frame is one-quarter inch in thickness and it is possible to grind a vee, it is better practice to do it, but if it is impossible to do this, additional care must be taken to be sure that the weld penetrates clear through to the inner surface of the channel.

Welding should begin on the underside of the frame, as shown in Figure 2. The weld should continue across the underside of the frame in an overhead position, up the side of the frame, in a vertical position, and across the top of the frame in a horizontal position. Figure 2 clearly indicates this method of welding.

Great care should be taken not to overheat the puddle. The heat should be maintained so that the puddle sparks as little as possible and the molten metal is thick and syrupy. The bottom of the channel should be reinforced heavily and the top of the channel similarly reinforced if such reinforcement will not interfere with the body. The side of the channel should be welded only flush with the surface of the steel. This is done because the reinforcement plate is placed in this instance on the outside of the channel and reinforcement of the weld would only have to be ground away.

The length of the reinforcement plate is not of great importance, but it should be at least twice the depth of the channel. If the channel is one-quarter inch in thickness, the plate should be the same thickness. A reinforcement plate placed on the outside of the channel is shown in Figure 3. If the channel is a six inch channel, the reinforcement plate should be five and one-half inches in width. This allows one-quarter inch at the top and bottom of the reinforcement plate for the welding of outside corner welds and means that the welds, when completed, will be flush with the top and bottom surfaces of the channel.

It will be noted in Figure 3 that the ends of the reinforcement plates are not welded. These welds are eliminated for a specific reason, namely, that welds across the ends of the plate would make areas of decreased strength across the back of the channel immediately along side of each end weld. This would, to a large extent, impair the value of the reinforcement plate. In other words, it would reproduce a condition at each end of the reinforcement plate which would be similar to the condition of the steel along side of the vertical weld of the break itself.

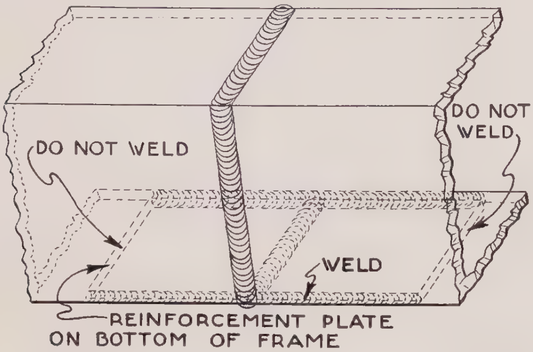


Figure 5—The Reinforcement Plate may be Placed on the Bottom of the Channel if Desired, and this Method Gives Excellent Results.

It may be that reinforcement across the top of the channel would interfere with the bearing surface of the body of the truck or car. If reinforcement across the top of the channel is objectionable and the welder can get at the inside of the channel, reinforcement can be made on the inside across the top and down the vertical leg of the channel. Reinforcement of the weld, where the additional metal does not interfere with some other part of the repair, is essential, because, as stated heretofore, the strength of the weld metal is not as great, per unit of area, as that of the original steel and in some way must be made as strong as possible.

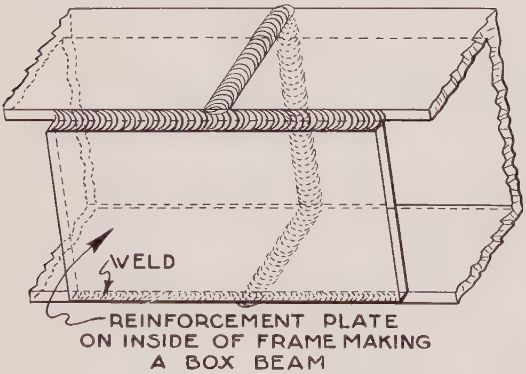


Figure 6—In this Instance the Reinforcement Plate is Shown on the Inside of the Frame, Making a Box Beam of the Frame.

In some instances it may be undesirable to place the reinforcement plate on the outside of the channel, because of interference of some other part, or because such a plate may be unsightly. In such instances the plate may be placed on the inside of the channel if this is accessible. This type of reinforcement is shown in Figure 4. It is made exactly the same as an outside reinforcement, except that the width of the plate is such that it will closely fit the inside of the channel. It should not, however, be so tight that it must be hammered into position, because it will expand during welding and might cause distortion if too tight.

Figure 5 shows the reinforcement plate on the bottom of the frame. The repair is otherwise made in identically the same manner as heretofore described, except that in this instance the reinforcement plate should be one-half inch narrower than the bottom of the channel if the channel is one-quarter of an inch in thickness. If the channel is three-sixteenths of an inch in thickness, the bottom plate should be three-eighths of an inch narrower than the bottom width. This makes an allowance for an outside corner weld in a ninety degree vee, as is clearly indicated in the figure.

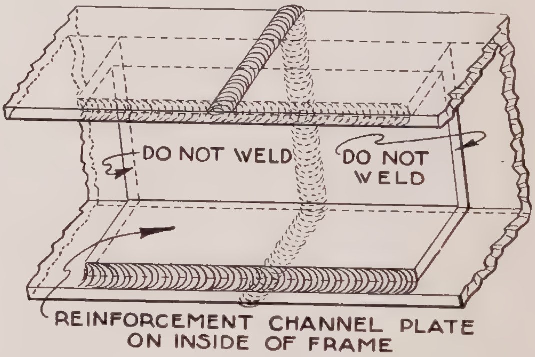


Figure 7—This is a Reinforcement Channel Instead of a Plate which has been Welded to the Inside of the Channel Frame.

When the inside of the frame is accessible, and for some reason it is not desired to reinforce the channel on the outside or on the bottom, an inside reinforcement plate may be used, as shown in Figure 6. This makes a box-like structure of the channel adjacent the weld and will give very satisfactory service.

A very heavy reinforcement can be made by forming up from a piece of plate a channel which will just fit inside of the channel of the frame. This is shown in Figure 7 and is welded as indicated. Such a reinforcement requires more time to make than the plate reinforcements but makes an excellent job.

It is hardly necessary to go into the advantages and disadvantages of these various types of reinforcements, because it is not always possible to choose more than one of them. The type of reinforcement will depend to a large extent on the location of the break and the accessibility of the frame. It will also depend upon the interference of other parts. It is, therefore, necessary for a welder to use good judgment in the selection of the type of reinforcement plate which he believes will most successfully accomplish the purpose. In any event, in all of the reinforcements shown, the ends of the reinforcement plates are not welded and should not be for the reasons given heretofore.

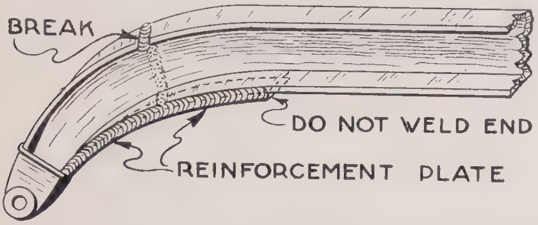


Figure 8—A Typical Weld at the Front of a Passenger Car Frame Where Breaks Sometimes Occur. The Reinforcement Plate is Welded to the Bottom of the Frame at the Sides but not Across the Ends.

Pointing Plow Shares

The blacksmith, in years gone by, pointed plow shares only with the expenditure of a very considerable amount of effort and time. Welding by the old forge method presented many problems, some of which made the pointing of a plow share a particularly laborious job. As it has done with many other processes in all industries, the oxy-acetylene torch has revolutionized the methods formerly used for pointing a share. The job can be done in fifteen minutes in the modern way, and the blacksmith shop equipped with welding and cutting torches has become the modern country welding shop. In the smaller town and village the pointing of plow shares may be a very profitable part of the business of the welding shop if properly done.

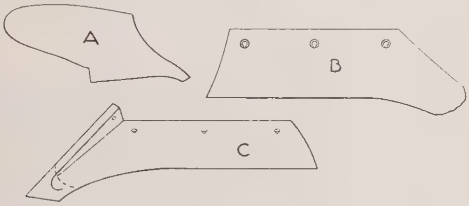


Figure 9—A is a Sketch of the Plow Share Attached to the Mold Board. B is a Sketch of One Side of a Plow Share with the Point Worn Off. C shows an Opposite View of the Share with the Point Indicated in Solid Line and the Worn Portion in Dotted Line.

This modern way is described and illustrated in the following paragraphs and sketches: In Figure 9 three views of a worn plow share are shown. A is a sketch of a plow share attached to the mold board in the position it occupies when fastened to the plow. It will be noted that the plow share is the lower portion including the point of the plow. B is a view of the side of a plow share with a worn point. C is a sketch of the opposite side of the plow share, showing the worn point in dotted lines and the original point in solid lines. The problem in this instance is to replace the point with a satisfactory, hard wearing point in the most economic manner.

It is possible nowadays to obtain plow points made of crucible steel. They are also made of electric steel. These are better wearing points than points made from old horseshoer's rasps, because they are especially made for the purpose of a grade of steel which will give the most satisfactory service. One side of one of these points is shown at E and the opposite side at F. As stated above, they are a commercial product and are supplied with the heavy section bevelled for oxy-acetylene welding.

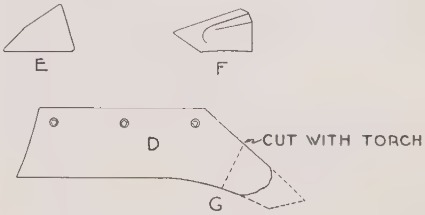


Figure 10—E Indicates One Side of the Crucible Steel Point before It is Welded. The Heavier Section of the Point is Bevelled Especially for Oxy-Acetylene Welding. F Shows the Opposite Side of the Crucible Steel Point. D is a Sketch Indicating the Manner in Which the Line of Cut May be Located with the New Point Laid along Side of the Worn Point.

One of these points is laid beside the worn plow share, as shown at D, Figure 10, and with a piece of chalk a line, G, is drawn at the end of the point. A cutting torch is then lighted and a cut made across the end of the plow share. The point is then placed in position, as shown at H, Figure 11, and tack welded at two points. Before tack welding care should be taken to see that oxide left by the cutting torch has been cleaned off of both edges of the share and that the point is properly lined up.

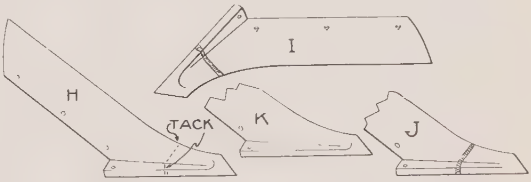


Figure 11—At H a Sketch is shown of the Share and the New Point Fitted into Position for Tack Welding. I and J Show Other Views of the Share and Indicate the Location of the Weld. At K the Finished Plow Share is Shown.

For welding the point to the share, a proper size welding tip should be selected, which can be determined as described in previous lessons, by the table in Chart No. 4, Lesson No. 2, and the thickness of the metal. The heavy section of the steel point is approximately one-half inch in thickness and the light section about three-sixteenths. The size tip required will, therefore, be No. 6 or No. 7.

A very good welding rod for the purpose is nickel steel. The American Welding Society have recommended an analysis for nickel steel welding rod, for welding high carbon steel and worn surfaces, where great resistance to abrasive wear is desired and where machining is not necessary. This analysis is as follows:

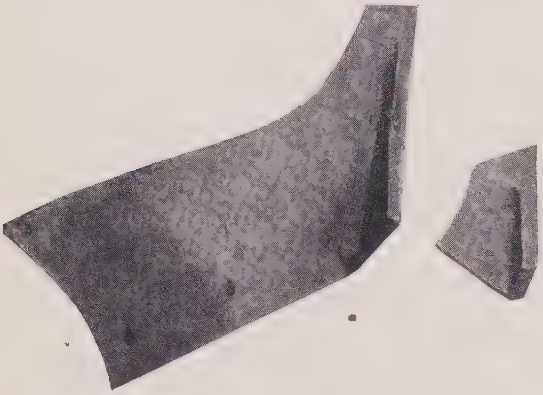


Figure 12—Photograph of a Welded Plow Share and a Crucible Steel Plow Point.

Nickel	3.25 — 3.75 per cent
Carbon	0.15 — 0.25 of 1 per cent
Manganese	0.50 — 0.80 of 1 per cent
Phosphorus	Not over 0.04 of 1 per cent
Sulphur	Not over 0.04 of 1 per cent

Three-sixteenths inch or one-quarter inch nickel steel rod should be used, or both, as may be desired.

Complete the weld across the heavy section between the point and the share where the point is veed and weld the light section up as shown at I in Figure 11. Turn the share over and complete the weld, as shown at J. It is now necessary to put the share in the forge and draw out the edges, harden, and let the share cool. The edges and the surface of the weld should now be ground smooth to complete the job, as shown at K. In Figure 12 a photograph of a welded plow share is shown, together with a crucible steel point before welding.

Fender Welding

The welding of a broken or cracked fender is not a difficult job, but requires care and skill to make a good weld and at the same time avoid distortion of the fender as much as possible. The principal difficulty lies in the fact that the metal around an old break in a fender is usually rusted away and does not present a good surface for welding. If the break is new, and the fender is eighteen gauge steel, of which most modern fenders are made, it can be welded without serious buckling. It is essential, however, to use a very small tip and a soft, neutral flame. The softer the flame and the less it "blows" the better. A suitable tip for the purpose is a small one having a main port equivalent to a No. 71 drill.

On some of the older model cars lighter gauge steel was used and in many instances the steel is so rusted away adjacent the break that new metal must be built out over the old surface in order to make a good weld. In such instances the repair is not easy and some buckling and roughness is likely to be the result. However, the fundamental principles of welding fenders are those already described for the welding of sheet steel. The weld should begin at the inside end of the break and continue toward the edge of the fender to the free end of the break.

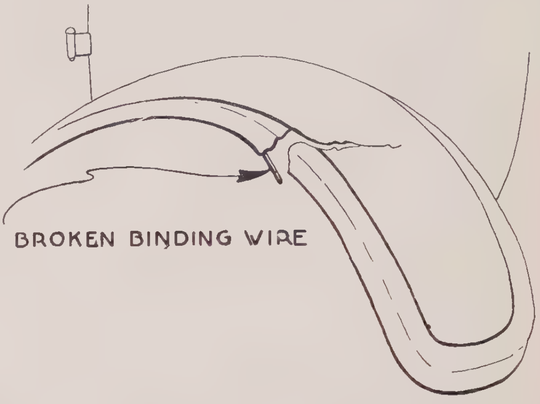


Figure 13—A Break in the Rear Fender of an Old Car Before Welding. The Binding Wire is Shown to the Left, Where It has Broken Away from the Metal.

When the metal is eighteen gauge steel and in good condition, no difficulty will be found in starting at the inside end of the break and continuing the weld toward the free end, even though the weld is not previously tack welded. The edges of the fender may be held together, if desired, by a small clamp or hand vise, or if necessary, a tack weld may be made where the edge of the metal is turned over the binding wire. Almost all of the older fenders and most of the newer ones are constructed with a wire bound in the edge.

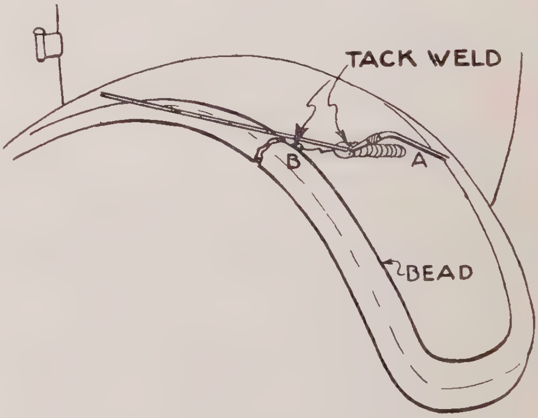


Figure 14—This Sketch Shows the same Break, as Illustrated in Figure 13, Half Welded. The Weld Will be Completed, from A to B, and Pounded to a Smooth, Even Contour with Two Hammers.

The welder will encounter all kinds of fenders if he makes a specialty of this class of work. These fenders will be in a great variety of conditions and cracks will be found in many locations.

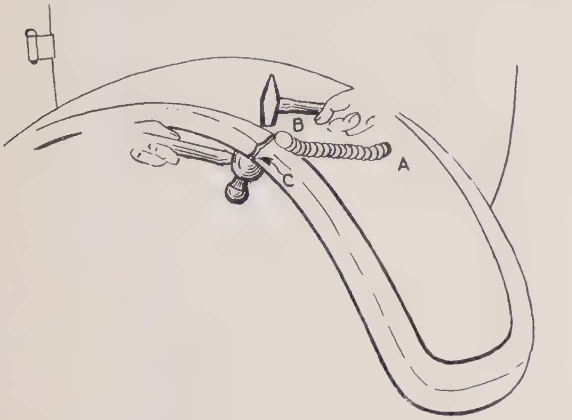


Figure 15—The Method of Hammering the Fender is Indicated in this Sketch. A Heavy Hammer is Used Underneath the Fender and a Lighter Hammer on Top. In This Manner the Edges Can be Kept Smooth and Even and the Original Contour of the Fender Maintained.

Sometimes these are along the running board, where the edge of the board is joined to the fender, or they may be toward the rear of the fender where it has been hit, or in almost any other position. Cracks are usually caused by collision with another car, a post, garage door, or something of that kind, and for this reason it is impossible to tell just where the break will occur.

Some welders prefer to use a larger tip than the one specified, often the No. 0, or the No. 1 tip for a large torch and to use one-eighth inch welding rod instead of three thirty-seconds, which is ordinarily recommended. This practice will depend entirely upon the preference of the welder and also upon the condition of the fender. In Figure 13 a break in the rear fender of an old car is shown. In this car the fenders were made of about twenty gauge steel. The break was old and rusty and the wire at the edge of the fender was broken.

Figure 16—Photograph Showing Partially Completed Weld Pounded to Shape as Indicated in Figure 15.

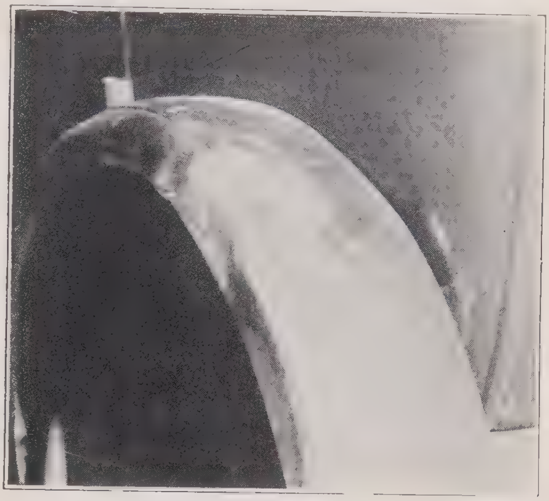


Figure 17—Photograph of the Completed Fender Weld. No Finishing has been Done and the Fender is Exactly as Left by the Torch. On an Old Fender of this Kind, It Is Hardly Possible to Make a Perfectly Smooth Job, but on the Heavier, Modern Fenders the Surface can be Finished with a Portable Grinder Until the Weld cannot be Detected.

The weld was started at A, Figure 14, and tack welded at two places as shown. Welding again began at A and was continued to B. The position of the tip and the rod was such that the rod blocked the heat as much as possible to avoid burning a hole through the light steel. The torch and the rod were both held still and a ripple weld was made with the puddle from one-eighth to three-sixteenths of an inch in width. The welding rod was held in line with and over the crack and a short piece of rod was used.

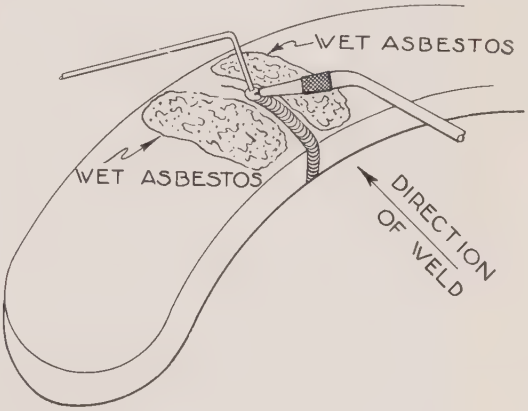


Figure 18—This Figure Shows a Method Often Used by Welders Who begin at the Bound Edge of the Fender and Work in Toward the Beginning of the Break. This Method is not Recommended. This Sketch also Shows the Use of Wet Asbestos which will be Found Very Handy to Protect the Painted Surface and to Prevent as Much Distortion of the Metal as Possible.

When the weld from A to B was completed, as shown in Figure 15, two hammers were used to pound the upper portion of the fender to its true shape. It is very essential that the fender should be shaped up in this manner, before the entire weld is completed, otherwise it may be more difficult to form the metal evenly.

The next step was to place the binding wire in line and weld it to the other broken end. The seam was welded between C and B, welding vertically up the break. The hammers were frequently used to keep the edges of the break even and to prevent distortion of the metal. The edge at C was then heavily reinforced by building up the metal around the binding wire and the fender as much as possible without making an unsightly lump of metal. In making the weld the welder allowed the puddle to sink as much as possible, so that the greater part of the weld was formed on the underside of the fender. Thus the reinforcement of the weld was underneath the fender and less refinishing on the top of the fender was required. If, in making the weld, one edge tends to overlap the other, the offending edge can be melted away slightly and pounded flat and even with the hammers; the weld can then be continued and will be smooth and even.

Figure 17 shows a photograph of the completed fender. It is only necessary to smooth up the surface as much as possible, paint the fender, and the job will be completed. With a portable grinder the weld can be smoothed up, so that it cannot be detected after the fender has been painted.

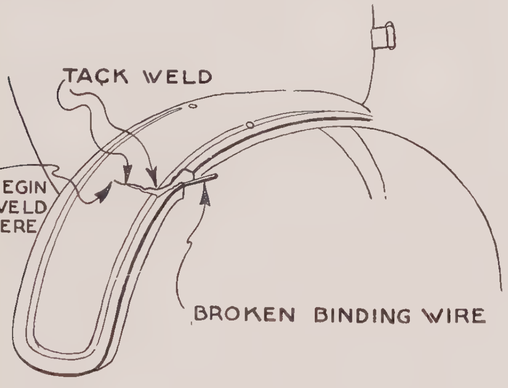


Figure 19—Sketch Illustrating a Break in an Old Type of Fender, One that the Welder is Often Called Upon to Repair.

Some welders claim that the first operation in making a fender weld is to straighten up the fender, weld the binding wire and then continue the weld in the direction shown in Figure 18 toward the inner end of the break. This can be done, but usually causes severe buckling as the weld progresses along the seam until finally there is considerable distortion at the end of the weld. It is believed to be better practice to start at the inner edge of the break and weld outward, rather than so to proceed that all expansion must be taken care of by the buckling up or down of the sheet steel. One of the important principles in sheet metal work, as heretofore described, is the separation of the edges of the seam at the end of the weld so that as the weld progresses these edges will draw together and just meet rather than overlap.

In Figure 18 wet asbestos is shown on each side of the seam. If the car is a new one, and the fender is expensive, it is desirable to protect the finish as much as possible. The wet asbestos may also be used to prevent the absorption of heat by the surrounding steel. Judicious use of asbestos paper torn and shredded into small pieces and soaked in water will be found advantageous. As stated above, there are a good many different types of fenders and many varieties of breaks. Each of these must be handled as individual conditions require.

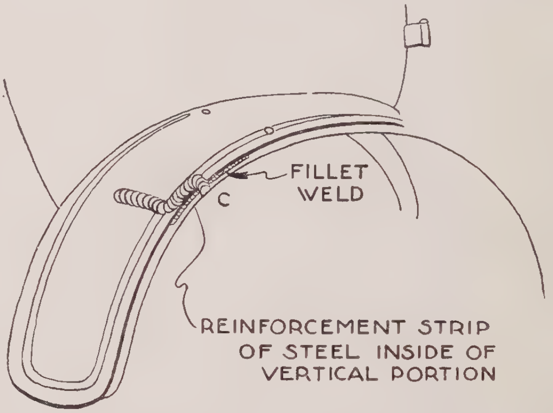


Figure 20—Sketch Showing the Completed Weld with the Fillet Reinforcement Under the Projecting Edge.

Figure 19 shows a break in an old fender of an early type. This fender is not made of one piece of steel pressed to shape, but of two pieces joined together by a lock seam, the edges of the metal being formed over a binding wire. A break of this kind would be handled exactly the same as that heretofore described, except that the vertical portion of the fender, C, should be heavily reinforced, either by increasing the thickness of the metal along this surface, or by welding a small strip of steel on the back of the fender. A fillet weld should also be built up along the under corner of the projecting portion of the fender as indicated in Figure 20. This figure also shows this fender welded and clearly indicates the methods used.

Welding Automobile Springs and High Carbon Steels

Automobile springs are usually made of a high carbon steel of approximately the following analysis:

Carbon	0.90 to 1.05
Manganese	0.25 to 0.50
Phosphorus Acid (Maximum)	0.05
Phosphorus Basic (Maximum)	0.04
Sulphur (Maximum)	0.05

They may also be made of silico-manganese, chrome-vanadium, or other alloy steels. When high carbon steel is melted with the oxy-acetylene flame, there is a zone along side of the molten puddle where the metal has been made brittle, or burned as the blacksmith would say, to such an extent that subsequent heat treatment will not restore its original properties. While, therefore, it is possible to weld a broken automobile spring, the result will be a union, or joint, which is likely to break along side of the weld. The quality of the steel in the weld will be entirely changed and it will be unsuited for the purpose for which the spring steel was originally made.

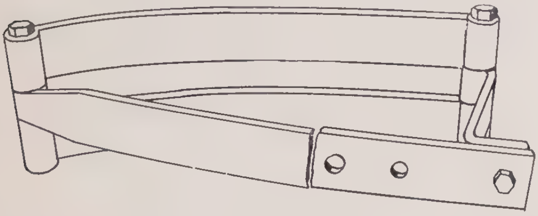


Figure 21—Sketch Showing a Broken Bumperette. This Bumper did not Break Through the Hole as Would be Expected, but Close to It.

In most instances where an automobile spring leaf is broken, it will be found far better practice to purchase a new spring leaf and put it in the spring than to attempt to weld the broken one. A broken spring should not be welded unless it is the only means for getting an automobile to a repair shop where a new leaf can be obtained. In this event the leaf should be reinforced, if possible, with a steel bar so that it is likely to hold up for the remainder of the journey.

Such a temporary repair could be accomplished to better advantage by bronze welding than by fusion welding with steel welding rods. Bronze welding is also used in connection with high carbon steel to join a high carbon steel tool to a machine steel shank. The whole subject of bronze welding, however, is discussed in later lessons and so will not be given attention here.

Welding Automobile Bumpers

Bumpers for automobiles are subject to shock and impact. They are placed upon a car to prevent damage to other parts in the event of a collision with another car or with some other object. For this reason, they must be constructed of a grade of steel, which will withstand the severe service for which they are intended. The grade of steel is, of course, dependent upon the make of the bumper and the choice of the manufacturer. Many of the older bumpers are made of bumper steel stock of from 0.75 to 0.90 per cent carbon. Like automobile frames this steel will be changed considerably in its characteristics when melted with the torch.

If a bumper is broken, as illustrated in Figure 21, and the break is welded in the usual manner, there is likely to be a zone of weakness beside the weld, because of the changes which have taken place in the steel as has been heretofore described in welding frames. For this reason the bumper repair should be made in almost identically the same manner. The break should be welded as usual, with low carbon steel rods or nickel steel rods. Nickel steel is preferable in most instances and will produce a stronger weld, but other high strength alloy rods will give satisfaction.

A reinforcement plate should be placed over the weld, as shown in Figure 22, and this plate welded along the top and bottom edge, but not across the ends. This practice is identical with that previously described in this lesson with reference to the welding of automobile frames. Of course, the location of the plate will depend largely on the nature of the break and whether or not it is possible to place the plate on the inside or the outside of the broken part. Usually a break in a bumper occurs through a hole for a fastening bolt. In this event, or if the reinforcement plate should interfere with other bolt holes, it is, of course, necessary to drill clear through the plate and to use longer bolts if required. If the location of the break is such that it is impossible to use a reinforcement plate, the weld should be made in an approved manner with nickel steel and the surface of the bumper bar adjacent the weld built up to a section considerably thicker than the bar itself. In this manner the weld may be reinforced with a strong reinforcing metal which will help to prevent its breaking adjacent the weld if it is called upon to resist another severe blow.

It is also possible to bronze weld a bumper repair, but as stated previously, bronze welding is a subject considered separately in these lessons and for this reason further comment upon it here is unnecessary.

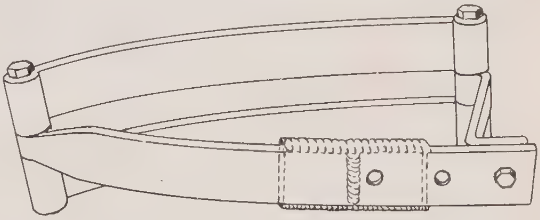


Figure 22—Sketch Showing the Welded Bumper with a Reinforcement Plate Placed Upon the Inside of the Bar Where It Does Not Interfere with the Brackets Which Attach It to the Car. This Reinforcement Plate was Welded at the Top and the Bottom, but Not at the Ends.

Welding Gasoline Tanks

Sometimes a gasoline tank of an automobile will spring a leak or become punctured or broken in some manner in an accident. The job shop may be called upon to weld such a tank. This can be done without difficulty, providing proper precautions are taken to prevent any possibility of the flame or the heat of the metal igniting whatever gasoline may be left in the tank and causing a severe explosion.

Everyone should know that an empty gasoline tank containing gasoline fumes may cause a disastrous explosion if the fumes, or the small quantity of gasoline within the tank, are lighted. This is particularly emphasized, because sometimes a man does not realize the danger until it is too late. The gasoline tank should be removed from the machine and thoroughly washed out with a hot solution of washing soda and water. Great care should be taken to see that the tank is absolutely clean on the inside and that there are no pockets, piping or valves which might hold a small quantity of gasoline. When this has been done, the tank should be completely filled with water up to the cap and the cap left off. If the part to be welded is in the upper part of the tank, the job can then be accomplished without difficulty.

If, however, the crack or break is in the lower part of the tank it may then become necessary to turn the tank over on its side and the cap must be placed over the opening to prevent the water from running out. If this were done without some means of release, the steam pressure created within the tank might cause it to burst. To prevent this, an old cap may be procured, a hole cut in the center and a piece of pipe welded to the cap. This piece of pipe may be bent around so that the open end will be a little higher than the tank and point upward when the gasoline tank is on its side. When the cap and the pipe are arranged in this manner, the water will remain in the tank, but it will be impossible for pressure to accumulate within it because the end of the pipe is not closed.

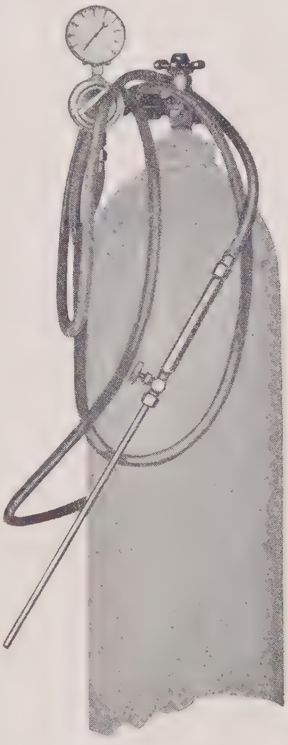


Figure 23—Illustration of a Carbon Burning Equipment Consisting of an Oxygen Cylinder, an Oxygen Regulator, Hose and a Carbon Burning Torch.

An automobile gasoline tank, of course, has a drain in the bottom from which the plug can be removed. If the break is in the bottom of the tank instead of the side, the cap of the tank could be put in place and the plug in the bottom hole removed and the tank filled up until overflowing with water. The important thing to remember in the welding of any gasoline tanks or oil drums is that the tank must always be filled completely full of water, after being washed clean, before welding is attempted. There must be no pockets or other confined spaces where gasoline or inflammable fumes might accumulate. Furthermore, it is always necessary to vent the tank in some manner so that the water will remain in it and the steam created by the heat will escape. If these precautions are taken there is no reason why gasoline tanks should not be welded with entire safety.

This same arrangement may be used for welding a break in a closed end of an oil or gasoline drum. In this event the pipe should be placed through the plug in the bung hole on the side and be bent until it will extend vertically up at least as high as the top of the tank. Steam is excellent for cleaning oil or gasoline drums before welding them. The steam hose should be attached to one opening in the tank and the steam allowed to flow out of the other. The tank should then be washed and filled with water as heretofore described.

Straightening Frames and Axles

An automobile will sometimes be towed to a job shop with a bent frame or a bent axle, caused by a collision or other accident. An oxy-acetylene torch offers a quick and convenient source of heat, which can be used to great advantage in straightening frames and axles. A large tip should be selected, usually a No. 8 or No. 9 and the part heated to a red heat where it must be bent back in position to be straight. A great variety of means can be used to apply the necessary pressure to the part to pull or push it back into line; the welder will have to use his ingenuity in this connection. The means utilized will depend entirely upon the local conditions in the shop and the kind of a bend which is encountered. The torch, however, can be used to apply the heat just where it is needed and in exactly the right amount. It has a further advantage in that it is portable and if oxygen and acetylene cylinders are used, can be moved to any part of the shop, or to the yard if the work is being done outside.

Carbon Burning

Carbon burning cannot be classed as welding, but it is part of the routine work of many job shops and most garages and may well be considered in this lesson. Deposits of carbon in the cylinders of automobiles and trucks are the result of incomplete combustion of the gasoline within the cylinders. A carbon knock is familiar to most automobile drivers and when carbon knocks become excessive the carbon can be removed from the cylinders, either mechanically by removing the cylinder head and scraping the carbon out, or by burning the carbon out with oxygen. There have been many carbon compounds and carbon removing devices offered to the public from time to time, but the most reliable methods are either of those mentioned above.

Burning the carbon out of cylinders with oxygen is a very easy job and requires but a few minutes. Carbon will burn in the presence of oxygen and there is not enough heat developed in the process to injure either the cylinders or the valves.

The equipment required for carbon burning is very simple, consisting of an oxygen cylinder of standard size; an oxygen regulator, preferably with two gauges, but one outlet pressure gauge will suffice; a length of hose and a carbon burning torch. The torch may be an attachment to a standard welding and cutting torch, or it may be a special torch for carbon burning. The torch, in the latter case, consists of a handle, a valve and a flexible copper tube. The tube is small enough to be inserted in the spark-plug opening and can be bent around so that the entire interior surface of the combustion chamber can be reached. Carbon burning requires about ten or fifteen pounds oxygen pressure at the regulator and about five cubic feet of oxygen per cylinder.

How to Burn Carbon from Cylinders

It is usually good practice to provide a fire extinguisher or have one available, if required, not too far away from the car. The gasoline feed to the carburetor should be disconnected or shut off and the engine run until the gasoline within the carburetor is consumed.

A piece of canvas or asbestos paper should be provided to spread over the engine to prevent sparks or fire from falling into the pan or possibly igniting oil or causing other damage. Either the canvas or the asbestos paper may have holes cut in it at each spark-plug, so that the operator can conveniently get at the spark-plugs. The connecting wires to each spark-plug should be removed and the plug and bushings, if any, removed.

The oxygen cylinder should be set near the car and the cylinder valve slightly opened as heretofore described in connecting a regulator. The oxygen regulator may then be attached to the cylinder valve, being sure that the adjusting screw is released and the cylinder valve opened. The oxygen hose and torch may then be connected in the usual manner and the regulator set to a pressure of approximately fifteen pounds with the torch valve open. The torch valve may then be closed.

The engine should now be cranked until the first piston in the front of the cylinder block stands at the top of the stroke with the valves closed. The position of the valves can be determined by looking at the tappets, or by feeling through the spark-plug hole with a short piece of welding rod. A small piece of oil saturated cotton waste should now be secured and dropped through the spark-plug hole into the cylinder. This should be followed by the flexible tip of the torch and the needle valve of the torch turned on, permitting oxygen to play upon the burning cotton waste. In a moment the carbon within the cylinder will catch fire and continue to burn without the addition of any other fuel. The oxygen should be directed over the interior surface of the cylinder above the piston including the valves. The carbon will burn as the oxygen is played over the surface until it is entirely consumed. It might be that during this operation the burning of the carbon will cease and another piece of waste will have to be lighted to start the reaction again. In this event, the same method heretofore described should be followed.

When the first cylinder is completed the engine should be cranked until the second piston is in the upper position with the valves closed and the carbon burned out of this cylinder in similar manner. The other cylinders should be treated likewise. When the job is finished, the oxygen should be turned off at the cylinder valve in order not to waste oxygen and the regulator screw released as heretofore described.

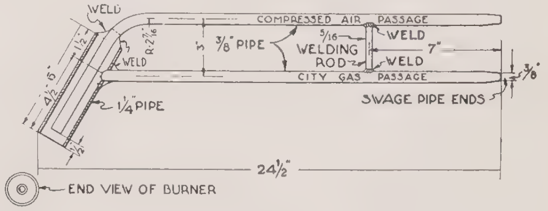


Figure 24—Sketch Illustrating an Efficient and Inexpensive Preheating Torch, Arranged to Use Compressed Air and City Gas. Where Air and City Gas are Available, This Torch will be Found Very Convenient for Many Purposes About the Shop.

A Home-made City Gas Preheating Torch

Where city gas is available, an excellent preheating torch, which can be used for many purposes about a welding shop, can be made entirely by welding and from pieces of scrap pipe. This torch will give an excellent flame for preheating small parts, during welding, or prior to welding, where only a small degree of heat is required and where the heat must be more or less localized. A few fire bricks, acting as baffles for the heat of one or two of these torches, produce an excellent preheating furnace.

The torch is made, as shown in Figure 24, twenty-four and one-half inches in length. Such torches can be made longer or shorter, as desired, but the size shown is a very convenient size for the average welding shop. No valves are placed upon the torch, because it is presumed that there is a valve at the outlet of the compressed air line and one at the outlet of the city gas line. A torch of this kind is rarely held in the hand and, therefore, no handle is required. It is usually laid upon fire bricks in such manner that the flame is directed where required.

The material required to construct this torch is as follows: One piece of one and one-quarter inch pipe six inches long; one piece of three-eighths inch pipe twenty-one inches long; one piece of three-eighths inch pipe twenty-six and five-eighths inches long; one piece of five-sixteenths inch welding rod two and seven-sixteenths inches long. The long piece of three-eighths inch pipe is bent, as shown in Figure 24, and slipped inside of the piece of one and one-quarter inch pipe. The angle of the bend is approximately sixty degrees. The end of the bent piece of three-eighths inch pipe should extend into the six-inch length of one and one-quarter inch pipe until it is within one-half inch of the end of this pipe and the bent portion parallel to it. It should then be welded at the upper end. This pipe is for compressed air. A hole is cut in the side of the one and one-quarter inch pipe of the same diameter as the internal diameter of the three-eighths inch pipe and this pipe welded to it, as indicated. The piece of five-sixteenths inch welding rod is then welded between the two pieces of three-eighth inch pipe.

The end of the two pieces of three-eighth inch pipe are swedged down at the hose end to three-eighths inch so that a three-eighths inch hose may be slipped over them and wired tight. Sometimes less heat is required than would normally be secured with this torch, with city gas and compressed air, as is often the case in welding aluminum, and in this event, city gas only is turned on and allowed to burn under the aluminum casting. In shops where such torches have been used extensively, all of the aluminum crank and transmission cases have been welded with city gas without air.

Weights of Steel Welding Rods

Size of Rod Inches	Pounds Per Thirty-six Inch Rod	Approx. No. of Thirty-six Inch Rods in Fifty Pound Bundle
1/16	.0312	1600
3/32	.0702	700
1/8	.1248	400
5/32	.1953	250
3/16	.2811	175
1/4	.5001	100
5/16	.7830	70
3/8	1.1274	45

This torch will be found very convenient in the average shop where compressed air and city gas are available and, as it is a steel welding job which can be done in the ordinary shop, it is described here. Preheating has not been discussed as yet and will not be until the lessons upon cast iron welding are reached. The entire subject of preheating will then be very thoroughly considered and other methods for preheating castings will be described in detail.

Job Sheet No. 9

Welding an Automobile Frame

The work called for in this lesson consists of welding and reinforcing a broken automobile or truck frame.

The student should procure several sections of frame about eight inches long, and some pieces of three-sixteenths or one-quarter inch steel plate, approximately twelve inches in length and about one-quarter inch narrower than the sections of frame.

After selecting the proper size tip and equipment and connecting it correctly, line up two sections of frame and tack weld them so as to hold them in position. Next, using C clamps, fasten the pieces to the edge of the welding table, allowing the break in the frame to extend over the edge of the table. Placing the work in this position enables the student to perform the welding in the manner encountered in the actual welding of a frame that is, overhead welding on the bottom of the break, vertical welding on the side and horizontal on the top.

As the text states, commence welding overhead at the inside, bottom edge of the frame and weld towards the outside. When the outside edge is reached change from overhead welding to vertical welding and continue up the side of the frame to the top, then weld horizontally until the inside, top edge is reached.

The frame should now be reinforced by welding a steel plate on the side of the frame as shown in Figure 3. Note that while the top and bottom edges of the plate are welded to the frame, the two ends are not welded. The reason for this has already been explained in the text.

Other sections of frame should be welded and reinforced in different ways until the student feels that he has mastered this type of work.

Questions:

1. What is the difference between the steel in an automobile or truck frame and the steel in a low carbon welding rod?
2. What is generally the cause of a break in a frame?
3. What is meant by "reinforcing an automobile or truck frame"?
4. What are some different methods of reinforcing?
5. Why are the ends of a reinforcing plate on a frame not welded?
6. What is meant by "pointing a plow share"?
7. Describe the manner in which a crack in a fender is welded?
8. At which end of the crack should the weld be started? Why?
9. How should automobile springs be welded?
10. Give a complete description of the proper method of welding broken bumpers.

Lesson No. 10

Miscellaneous Applications of Welding to Steel. Welding and Cutting in the Steel Foundry.

IT is intended in this lesson to cover as many special applications of welding to steel as space permits. Also to describe in general the use of welding and cutting torches in the steel foundry. This lesson concludes the lessons on the welding of steel and Lesson No. 11 begins the subject Bronze Welding Cast Iron.

Repairing of steel automobile bodies is a field for welding which may be made a profitable part of the work accomplished by the welding shop. There is no reason why the welding shop should take the attitude that such work is highly specialized and must be accomplished only in a body shop. If the welding shop is proficient, fully understands this class of work and is equipped with the few necessary tools to accomplish it, body welding may be easily carried on to the advantage of both the blacksmith and the welding shop equipped with welding apparatus.

The building up of hard cutting and abrasion resisting surfaces upon tools, dies, etc., is a very important subject and one which can be made quite profitable in the welding shop if fully understood.

Despite the fact that Ford Model A wheels are very strongly and rigidly made, they will of necessity be brought into the welding shop with broken spokes. It is true that a good jig is required to accomplish this work, but the jig is not prohibitive in cost and this repair can be made a profitable portion of the output of the job shop.

Farm implements always represent a large field for the repair man. The few jobs described in this lesson represent but a very small portion of the work which can be done by the blacksmith shop properly equipped with welding apparatus to assist the farmer in maintaining his equipment in working condition.

Another field covered to a limited extent in this lesson is the application of welding and cutting in the steel foundry. The cutting torch has completely revolutionized the design of steel castings, because it has enabled the designer to place the risers, sprues, runners, etc., where they should go to provide the proper flow of and pressure upon the metal. When the cold saw was used to remove risers, it was necessary to place them with due regard to their removal as there were many locations on a casting where the saw could not economically cut a riser off. The oxy-acetylene torch will cut the riser regardless of where it is located and accomplish this removal quickly and economically.

It is important that the welder fully understand the various grades of welding rods upon the market and use them where each grade will best suit the requirement. For this reason the subject of welding rods has been fully discussed and a table has been given showing the analyses of steel rods in common use and the classes of work for which they are best suited. Care in the selection and use of welding rods will be found well worth the special attention of the progressive welder.

Repairing Broken and Bent All-Steel Automobile Bodies

Accidents to automobiles frequently cause dented, bent and broken automobile bodies. Such repairs will often be required of the welding shop and there is no reason why the average shop should not be equipped with the necessary tools and knowledge to carry on this work to advantage.

There are, of course, many automobile bodies which are made of a wood frame covered with a steel sheathing. These are the older type bodies and present some problems insofar as repair is concerned, not found in the modern all-steel body which in recent years has become more and more common.

As the welding of a part wood, part steel body presents individual problems which the welder will have to solve, depending entirely upon the existing conditions, the remarks made here will be confined entirely to steel bodies. The same practice is applicable to the steel-wood bodies, but some means must be found to protect the wood if the metal is heated. With the all-steel body this is not necessary because in this type of construction no wood is used.

It is necessary, however, to protect the upholstery on the inside of the car from damage and to protect the paint as far as possible. For this purpose wet asbestos is very valuable to confine the heat to a given area and to protect the paint adjacent to the metal being welded or straightened. It will also be found an excellent means to prevent the buckling of the metal adjacent to the weld caused by the spreading of the heat. The welding rod used should be the usual low carbon steel of the American Welding Society specifications, G No. 1A, one-sixteenth or three thirty-seconds of an inch in diameter.

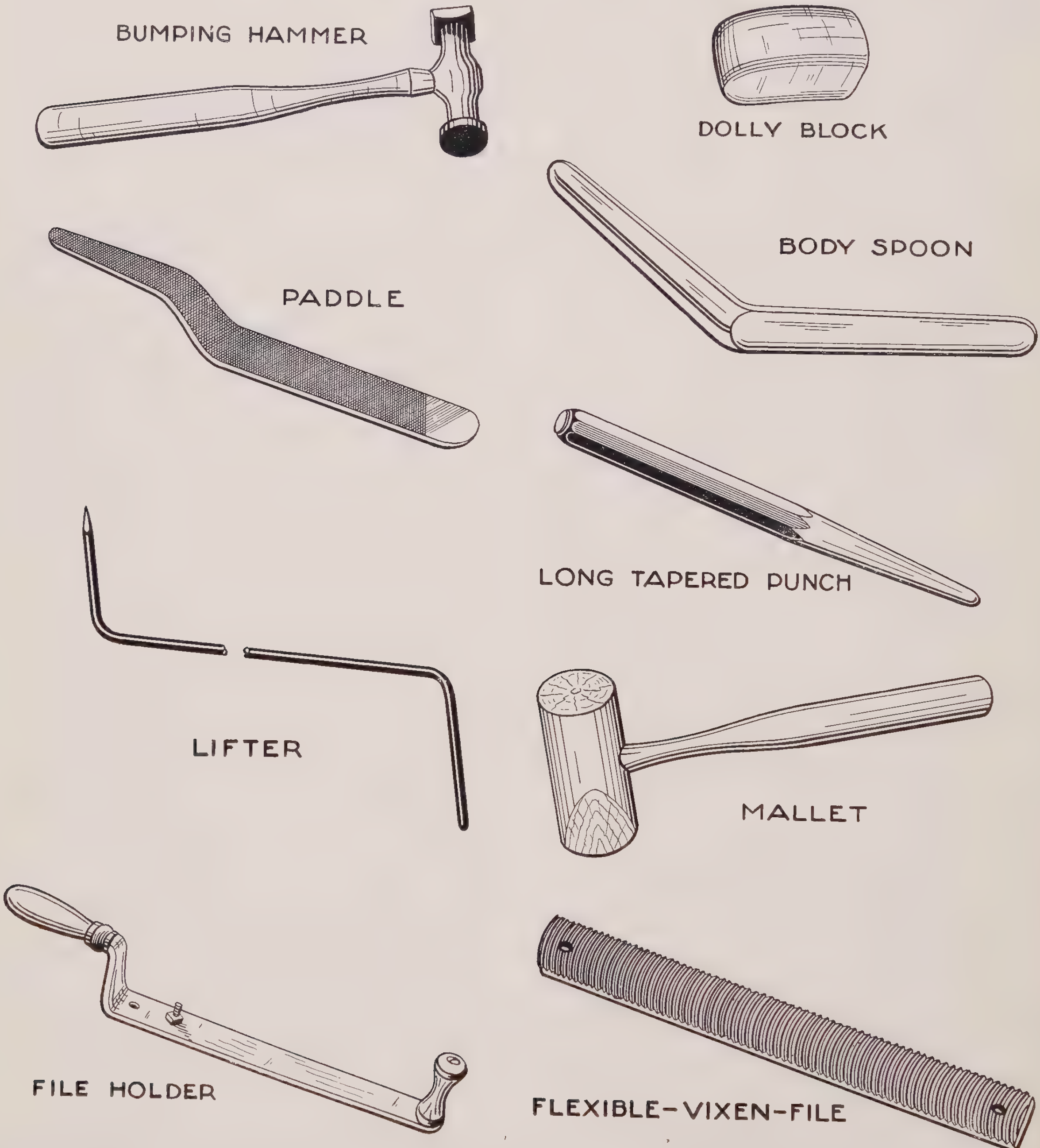


Figure 1—Sketches Illustrating the More Important Tools Required for Repairing Automobile Bodies. These are Recommended by the Edward G. Budd Manufacturing Company and May Be Obtained from Them if Desired.

Certain tools are necessary and the following are recommended by the Edward G. Budd Manufacturing Company of Philadelphia and Detroit, makers of Budd all-steel bodies. These tools can be procured from them or from local jobbers.

One drop forged steel dolly block weighing three pounds.

One fourteen ounce bumping hammer having a head four inches long, one end of which has a round face one and one-quarter inches in diameter and the other end a square face one and one-quarter inches square. The overall length of the hammer and handle should be twelve inches.

One twelve inch gum or dogwood mallet having a head five inches long and two and one-quarter inches in diameter.

One one and one-quarter pound file holder twenty inches in length, Stanley No. 607, or equivalent.

One fourteen inch flexible "Vixen" file weighing eight ounces.

One eight ounce body spoon three-quarter inches at the point, one and three-sixteenth inches at the heel, five inches in length and ten and three-quarter inches in overall length.

One long tapered punch three-sixteenth inches in diameter at the point, made of one-half inch steel, nine inches long.

One Budd design paddle made from a fourteen inch lathe-mill file.

One lifter made of one-quarter inch or three-eighth inch drill rod, bent to a Z shape and pointed at one end.

These tools will be found very convenient and some of them may be "home-made" if desired. Another useful piece of equipment is a sand bag, eight inches long, six inches wide and four inches thick, made of leather and filled with sand.

The sand bag is particularly valuable for removing large buckles when it is desired not to injure the surface any more than necessary. The wood mallet is used to pound against the sand bag.

A large buckle in the body may be straightened out by heating the center of the buckle to a red heat, holding the dolly block underneath the heated section, and pounding it until cold with the wood mallet. Small buckles may be beaten out of the sheet by holding the dolly block on one side and using the paddle on the other, to pound out the buckle.

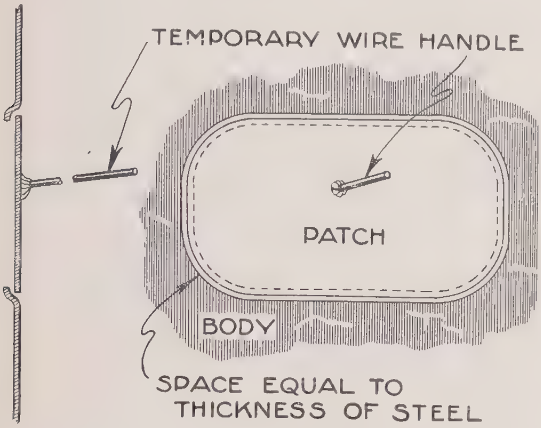


Figure 2—Sketch Showing a Patch for a Defect Cut Out of an Automobile Body. The Hole Should Be Large Enough to Include All of the Defects and the Edges Should Be Bent Over as Indicated. The Patch Should Be Slightly Smaller than the Hole and a Temporary Wire Handle Should Be Welded to It to Facilitate Handling.

There are cases where inside panels prevent the use of a block and a mallet as heretofore described. In such instances the tapered punch may be used to punch a hole through the inside panel and the lifter used to pry the buckle out of the outside sheet. The hole may then be welded closed.

When the metal has been so badly injured that the repair cannot be made by bending and forming into shape, the piece may be cut out and a patch inserted. The patch should be oval, or have straight sides but rounded corners. The metal of the body at the edges of the hole, which has been cut in the body, should be bent over as illustrated in Figure 2.

The patch is cut to such size that there will be a space between the patch edge at the body equal approximately to the thickness of the metal. A piece of welding rod may be welded to the center of the patch horizontally and a little above the center of the patch vertically, temporarily to hold the patch in position while it is being tack welded. The patch should be tack welded at four points as illustrated in Figure 3, making the tack welds at the opposite sides of the patch. Welding should be accomplished just as has heretofore been described for pipe welding, that is, welding across the top of the patch, then across the bottom, then at one end, and finally at the opposite end. This is done in order to equalize the heat as much as possible. Prior to welding or tacking the entire patch should be surrounded with wet asbestos in order to protect the adjacent metal as much as possible from the heat of the torch. The patch should then be shaped to the contour of the body with the mallet and the dolly block.

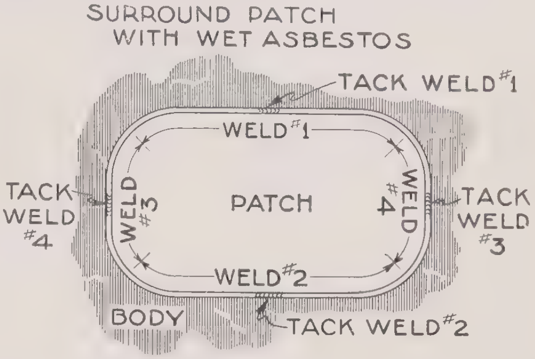


Figure 3—Sketch Showing Method of Tack Welding and Procedure in Welding. The Entire Patch Should be Surrounded by Wet Asbestos to Prevent the Heat from Injuring the Adjacent Metal.

It may be necessary to dish or form the patch to the contour of the body before welding it in position. This may be done from a flat piece of sheet metal cut to the right size by pounding it over a suitably shaped wooden block until it has the desired shape.

Sometimes it is necessary to draw out a buckle or dent in the body when an interior panel or some obstruction prevents getting at the inside. In this event a piece of welding wire may be welded to the center of the buckle. The area around the buckle may be heated to a red heat and the buckled area pulled out to contour by pulling on the welding wire. This method is clearly indicated in Figure 4.

Solder may be used to smooth up a rough surface if desired, or to straighten a bead on the outside where it would be difficult actually to straighten the bead in the steel of the body. In such cases the solder is built up on the outside of the steel and then formed to the contour of the bead.

Sometimes the doors are bent so that they bind in closing or possibly do not shut tight enough, indicating that the door hinges have been sprung. When it is necessary to spring the door to throw it away from the hinge post, this can be done by placing a steel bar in the opening, as indicated in Figure 5, and gently opening the door.

On the other hand, to throw the door toward the hinge at the left, a steel rod may be placed as indicated in Figure 6, and the door closed gently. The sketches clearly illustrate these two methods.

Building a Hard Surface on Tools, Drills, Bits, Etc.

The building up of a hard surface on drills, bits, core barrels and other tools used in the oil fields and upon various dies, cutting tools, teeth, etc., has become very common practice. There are many alloy welding rods used for this purpose, those described being Stellite, Stoody Rod and Stoodite. All of these metals are furnished by the companies who manufacture them in the form of welding rods so that a surface or armour plate may be built up upon the parts producing a tremendously hard cutting edge or face. An application of these metals to the worn edge of plow shares should be profitable to most country welding shops.

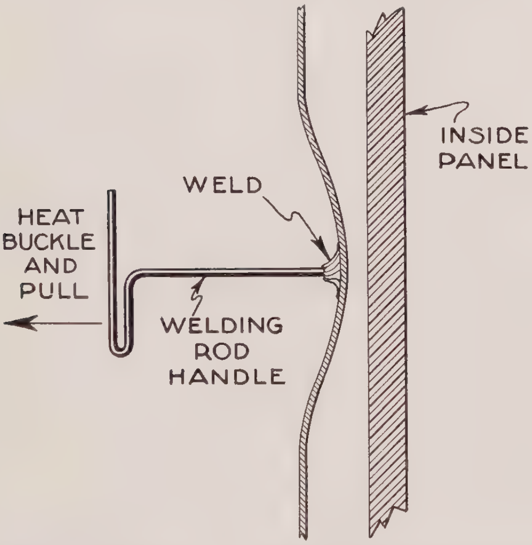


Figure 4—This Sketch Shows a Buckle in the Metal of the Body Where an Inside Panel or Some Other Obstruction Prevents Pounding Out the Metal from the Rear. In Such Cases, the Buckle Should be Heated and a Welding Wire Handle Welded to It. It may be Pulled Out Straight While the Steel is Hot.

Stellite is an alloy consisting essentially of chromium, cobalt and tungsten. It is made in one-quarter, five-sixteenths and three-eighths inch welding rods and it retains its hardness almost unimpaired until heated to a bright red. This is several hundred degrees higher than the temperature at which high speed steel will begin to soften. Stellite, after being cooled, resumes its original hardness and its action in this respect is quite different from that of steel which ordinarily is annealed by heating it in similar manner. The melting point of Stellite welding rod is approximately 2336 degrees Fahrenheit. It will be noticed that this is a little lower than the melting point of high carbon steel; this fact is particularly important when applying Stellite to the edges or faces of the parts to be armoured in this manner.

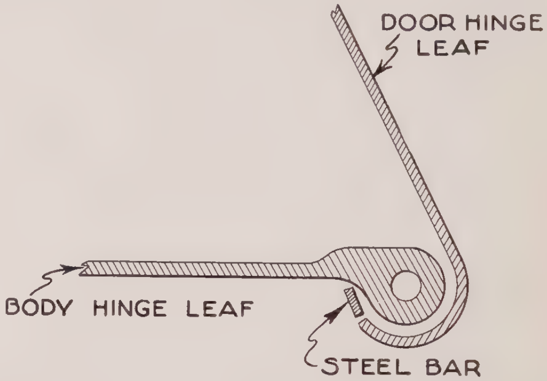


Figure 5—This Sketch Shows a Method for Bending the Door Hinge Away from the Hinge Post.

Stellite can be applied to almost any metal in common use. Any grade of steel, regardless of its carbon content, alloy steels of all compositions, cast iron, semi-steel and malleable iron can all be successfully armoured with Stellite.

Scale, rust or dirt should be ground or brushed away from the surface to be covered, either with a grinding wheel or a wire brush. It is essential that the surface be absolutely clean, but flux is not necessary under ordinary conditions. If, however, it is impossible on account of the shape of the piece to get at the surface with a grinding wheel, then a good grade of brazing flux may be used, but care should be taken not to use too much.

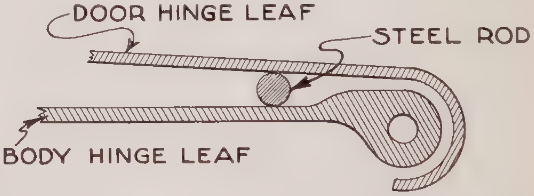


Figure 6—In this Sketch a Steel Rod is Used to Bend the Door Hinge Toward the Hinge Post.

When the piece to be hard faced has been properly cleaned and alined, it should be preheated, if necessary, to a medium cherry heat, approximately 1200 degrees Fahrenheit. Sometimes the entire piece should be brought up to this temperature before any hard facing metal is applied. Preheating may be done with a gas flame and a temporary fire brick preheating furnace, with charcoal, or, if the piece is small, with the torch. When the torch is used for preheating, the flame should be adjusted to a neutral flame.

The tip assembly used for applying hard facing metal should be approximately one size larger than would ordinarily be used for steel of the same thickness. The tip should be held, however, in a horizontal position so that the flame will be parallel to the top of the surface being faced and will not be directed at the surface. During hard facing an excess of acetylene should be used in the flame. That is, the flame should be adjusted until it has carbonizing characteristics. These are shown in Chart No. 3, Lesson No. 1, at "B."

The excess of acetylene required can be quickly determined by a little experimental work. Too little acetylene will cause the facing metal to bubble and foam, thus producing blow holes in the hard metal surface. Too much acetylene, on the other hand, will cause an excessive coating of carbon surrounding the molten metal and will very much slow down the operation. The envelope of the flame should always be held so that it will completely cover the puddle of hard facing metal. If this is not done the molten metal will absorb oxygen from the air.

Applying this facing metal is not welding in the sense that the word has been used heretofore in these lessons. It is a brazing process because while the facing metal itself is actually fused or melted, the tool to which the metal is being applied is not deeply melted, but is maintained only at a temperature where it just begins to sweat.

It is important that this point be given particular emphasis because some welders try to fuse the hard metal and the steel to which it is being applied just as in ordinary welding, with results which are far from satisfactory. The sweating heat, just referred to, is approximately a white heat, about 2200 degrees Fahrenheit. The steel must be hot enough so that the facing metal will flow or "tin" the surface. In this connection the melting temperature of the facing metal should be remembered and the steel brought very close to this temperature.

When applied in this manner the facing metal will flow on the steel tool nicely and fuse with it. The rod should be kept in the molten puddle of hard facing metal, but should be held quietly in order not to mix the facing metal any more than necessary with the surface of steel. The facing metal will run under the surface of the scale and other impurities and cause them to float to the surface.

Impurities which will not float to the surface of the metal must be worked out by melting the surface of the steel slightly deeper and manipulating the impurities with the rod. In all instances, however, when difficulty of this kind is encountered the surface of the steel should be fused to as little depth as possible and care taken to prevent the mixture of the facing metal and the steel.

When the surface has been tinned with facing metal in this manner and all blow holes and impurities eliminated, the section should be built up to the necessary thickness and width. Building up on the tinned hard metal surface is comparatively easy because like metal is being added and as the melting points of both the rod and the base metal are alike, no difficulty is encountered.

The tinned area should not be made larger than can be built up by the operator without interruption. When a piece of metal has been hard surfaced and the heat has warped it out of shape, it cannot be pounded back to its original contour. Therefore, in applying hard facing metal, care should be taken to direct the heat so that the effect upon the steel will be compensated as far as possible and warping will be prevented. Where a large section of surface is to be hard faced at one time, it is better practice to tin and build up the metal to the required dimensions in sections, rather than to attempt to tin the entire area and then build up the surface.

Some hard facing metals flow very much like cast iron; hence, for square corners the metal should be built in a round bead to a greater thickness at the corner and afterwards ground off until square.

When the piece has been completed it should be reheated to an even heat throughout and placed either in an oven or an annealing box and allowed to cool slowly. If the piece was originally heated in a rough fire brick furnace, using charcoal as a source of heat, it can be reheated, after hard facing, by putting some more charcoal in the furnace, covering the entire furnace with asbestos paper, wrapping it tight and allowing the piece to cool with the dying fire. Slow and even cooling of the piece is essential.

Stellite is made by the Haynes Stellite Company of Kokomo, Ind. It is supplied in one-quarter, five-sixteenths and three-eighths inch diameter welding rods and the average lengths are eight inches, ten inches and eleven inches respectively. It is made in several grades. No. 1 is the hardest and resists abrasion to a greater extent than No. 12 or No. 6. It should be used only for coating surfaces which are subjected to extreme abrasion, but to little shock. The expansion, when heated, of grade No. 1 is less than that of carbon steel and if it is applied to large areas, small cracks may appear.

Grades No. 12 and No. 6 are a little softer than Grade No. 1, but are considerably tougher. Grade No. 12 should be used to coat surfaces where shock in addition to abrasive wear is encountered. Grade No. 6 will expand, when heated, essentially the same as carbon steel and when large areas are coated cracks are not likely to occur.

Weight of Stellite Rod Per Inch

¼ inch	0.0175 pounds
5/16 inch	0.027 pounds
⅜ inch	0.038 pounds

Weight of Stellite Per Square Inch of Surface

1/16 inch thick	0.0194 pounds
1/8 inch thick	0.0388 pounds
3/16 inch thick	0.0582 pounds
1/4 inch thick	0.0776 pounds

Stoodite and Stoody rods are furnished by the Stoody Company of Whittier, Calif. Stoodite is made as an alloy rod. Stoody rod, on the other hand, is made by forming a flat piece of steel into a cylindrical tube, enclosing special alloys which give it its self-hardening qualities. Stoody rod is made in one size, which is slightly more than three-sixteenth inches in diameter and twenty-eight inches long. The melting point of Stoodite is about 2400 degrees Fahrenheit.

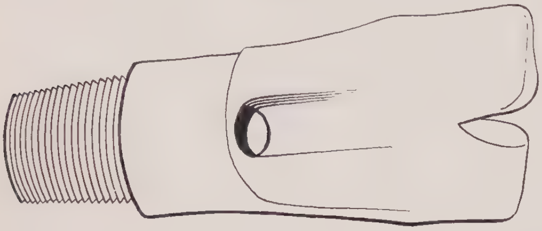


Figure 7—A Fish-tail Drill Bit with the Points Worn Off.

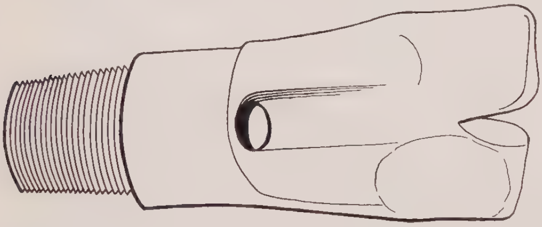


Figure 8—The First Step is the Melting Off of Any Hard Facing Metal, Which may Have Previously Been Applied to the Bit.

It is not recommended by the Stoody Company that this metal be applied by the brazing process, which is essential to the application of some of the other hard facing metals, but that the Stoody rod be fused deeply to the surface of the fused steel. In other words, the application of Stoodite to the surface of a tool or bit is welding and not brazing. Stoodite is used to a very great extent for the hard facing of drilling tools in the oil fields. A typical example of this class of work is the building up of fish-tail bits.

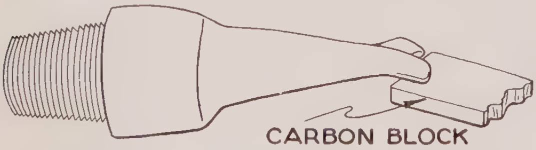


Figure 9—The Bit Should be Laid with One of the Blades Over a Carbon Block, as Indicated.

The various steps in building up a fish-tail bit are shown in Figures 7 to 12. In Figure 7 the bit is illustrated as it comes from the well, essentially worn out. The first step in the repair is the removal of any hard facing metal which has previously been applied to it. The bit after the removal of the hard facing metal is shown in Figure 8. The next step is to place the bit with one of the worn blades resting upon a carbon block, fire brick, or some other refractory surface, as illustrated in Figure 9. Figure 10 shows the building out of a blade or tooth of the bit with high carbon steel. Figure 11 illustrates the high carbon weld of the blade or tooth, completed to the original contour. The bit is then turned over and the other tooth treated in the same manner.

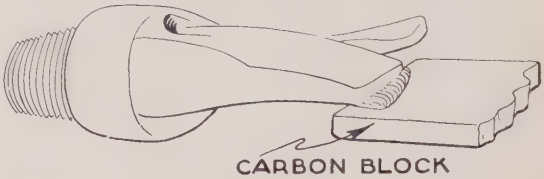


Figure 10—The Blades Should be Built Out with High Carbon Steel.

Figure 12 shows the hard facing metal applied to the bit on the surface which first comes in contact with the formation of the rock or shale, as the drill bit rotates. It is essential that the hard facing metal be applied to this surface and not to the back of the tooth. It should extend from the crotch or center of the bit to the extreme point. The thickness of the facing metal should be approximately one-eighth inch or more at the crotch and should be increased to about one-half inch or more at the cutting edge of the bit upon large sizes.

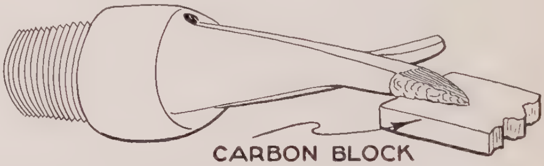


Figure 11—One of the Blades Built to Its Original Contour with High Carbon Steel. The Bit Should be Turned Over and the Other Blade Treated in Similar Manner.

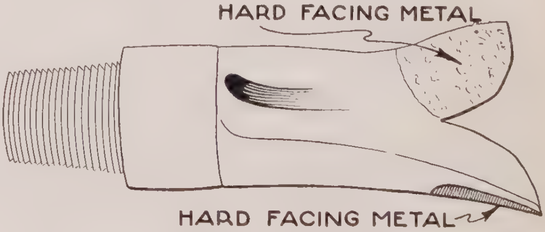


Figure 12—The Hard Facing Metal Applied to the Surface of the Built Up Blade.

Some welders will attempt to face both sides of a bit of this kind, but this practice is obviously unsatisfactory, because in this event the drill would wear down blunt and not sharp. It must be sharp to cut the formation and if built up only upon the side first coming in contact with the rock as the drill rotates, the hard facing metal will contact with it first, but the softer metal to the rear of the blade will wear away always maintaining a sharp cutting edge of hard metal. This principle should be followed in the facing of tools or teeth, or of plow shares. It is just as important that the hard facing metal be applied to a plow share in the proper manner as to a drill bit, because the plow share must wear in such manner that the edge will be self-sharpening and not become rounded, blunt and dull.

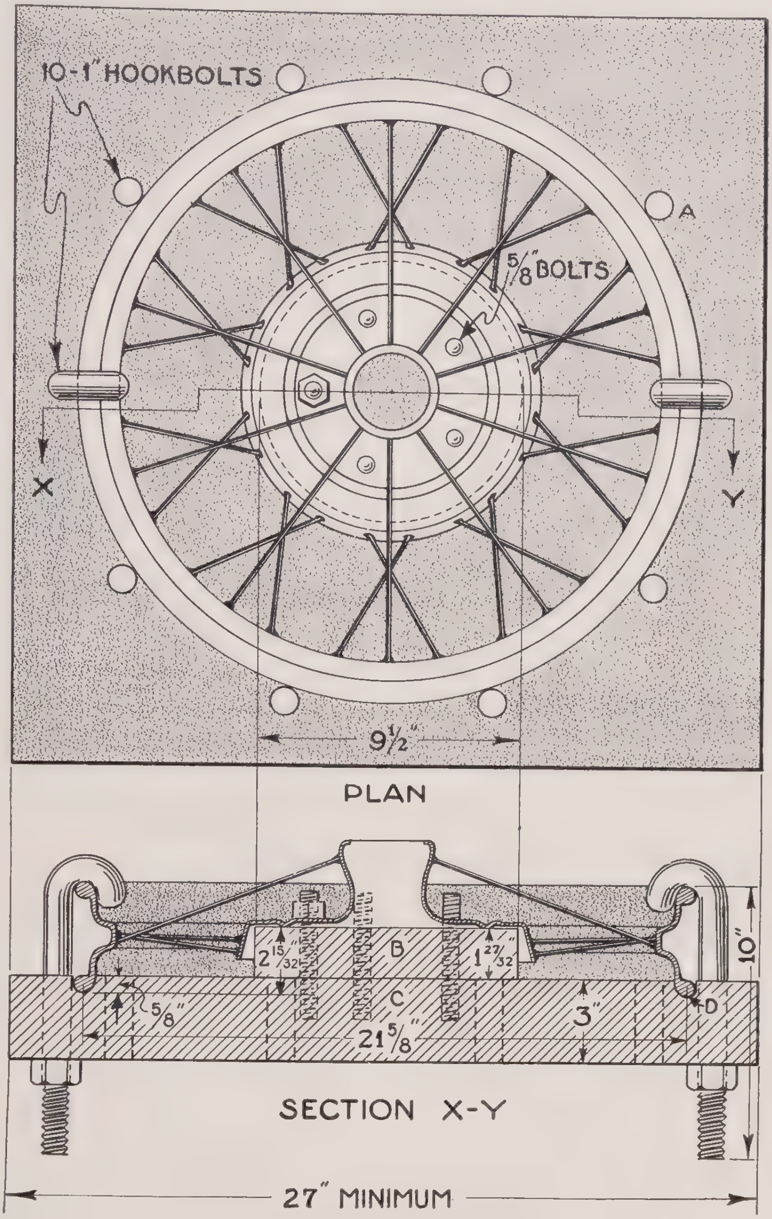


Figure 13—Plan and Sectional View of a Special Jig for the Welding of Broken Spokes for 1929 Model A Wheels.

Welding a Model A Ford Wheel

Broken spokes in a Model A Ford wheel or a bent rim can be repaired with the oxy-acetylene torch provided a proper jig is available. It will be appreciated that the moment heat is applied either to the spokes or the rim, or a weld made between several broken spokes and the rim, the heat and subsequent contraction is likely to warp the rim out of true. There is no difficulty in welding the spokes to the rim as the steel flows nicely and makes an excellent weld. Warping, however, must be taken care of or the rim will not run true when the job is completed. The jig suggested for this work is a simple one, but must be made for the purpose and for this reason may be somewhat expensive, but not too expensive to make the repair of Ford wheels unprofitable to the welding shop equipped with such facilities.

The jig consists of a square or round cast-iron block, C, having minimum dimensions of 27 inches and being approximately 3 inches in thickness. An old planer bed-plate may be used for the purpose if desired. A circular block, B, 9½ inches in diameter and one and 27/32 inches in thickness, should be planed true and even and drilled for the ⅝ inch stud bolts which project from the lower plate, upward through the five holes in the block and through the front center portion of the wheel. The spacing of these bolts is identical with the spacing of the five bolts which fasten the wheel to the bearing section and brake drum upon the car. A groove, D, ⅝ of an inch in depth should be cut in the lower plate exactly to fit the wheel rim. Around the outside circumference of this groove, ten holes should be drilled for the ten one-inch hook-bolts, A, shown in the drawing, Figure 13.

If several spokes are broken at one place in a wheel, but the wheel rim is not out of line to any extent, the wheel should be placed in the jig and all bolts screwed down tightly. Wet asbestos should be used to confine the heat as largely as possible to the point being welded and the broken spokes welded to the rim. Bending the spokes slightly before welding is sometimes found advantageous to help compensate for expansion.

The adjoining spokes to the point of repair should then be adjusted with heat, if they have been strained until the rim and the spokes adjacent to the repair, are in normal condition. The hook bolts may be loosened up or tightened down as occasion may require, and considerable ingenuity on the part of the welder may be necessary, at times, to manipulate the repair in such manner that heat will be applied at the right point and will not unnecessarily warp the rim out of true. If it becomes warped, or if it is warped or bent in the first instance by the accident which originally broke the spokes, the hook-bolts need not be tightened down at first but tightened gradually as heat is applied, where required, to bring the rim down to a true position.

No specific instructions can be given for such a repair and the welder will have to experiment until he finds the best method to pursue. Of course the manner of procedure will depend entirely upon the kind of repair required. The welding rod used should be low carbon steel of the American Welding Society specifications G No. 1 A.

Various Grades of Steel Welding Rod for Miscellaneous Purposes

The selection of a proper welding rod for the work to be done is especially important. An effort has been made throughout these lessons to indicate to the welder that the various grades of steel require rods having proper analyses to meet the requirements of the work. In many instances, the low carbon steel rod will answer the purpose to excellent advantage, but in other instances, where the steel is an alloy steel, or where the carbon content is higher, special welding rods will be found to produce stronger welds or harder welds as may be required.

So far in these lessons, reference has been made to the low carbon steel rod, manufactured under the American Welding Society specification No. G-1 A and to the Nickel Steel Welding Rod also manufactured under the American Welding Society specification for nickel steel. Other rods containing varying amounts of carbon and other elements have not been considered.

Some combinations of the elements carbon, manganese, and silicon in welding rods have been patented. For instance, the Becket patent No. 1,452,781 issued April 24, 1923, claims an iron alloy containing carbon and substantial amounts of manganese and silicon. Seven claims were allowed on this patent, covering various percentages of these elements.

This alloy is said to produce a welding rod with which a considerably stronger weld can be made than with low carbon steel. Under this patent, a rod has been manufactured by one of the large companies known as the High Test Rod. This rod has been fully described in a paper presented at the fall meeting of the American Welding Society in Boston in October, 1925, by Mr. J. R. Dawson. Some interesting figures were given in this paper, showing the relative amounts of carbon, manganese, and silicon in the low carbon rod, which has been called Norway Iron Rod; in mild steel rod, and the High Test Rod before mentioned. Figures are also given in reference to the various quantities of these elements remaining in the weld obtained with these various rods. The table is given herewith.

Table 1

Composition of Welding Rods

	Norway Iron Rod	Mild Steel Rod	"High Test Rod"
Per Cent Carbon	0.05	0.25	0.20
Per Cent Manganese	0.15	0.45	0.80
Per Cent Silicon	0.01	0.02	0.55

Composition of Weld Metal Obtained From

	Norway Iron Rod	Mild Steel Rod	"High Test Rod"
Per Cent Carbon	0.03	0.08	0.18
Per Cent Manganese	0.07	0.20	0.48
Per Cent Silicon	0.01	0.01	0.25

Some other very interesting figures have been given in this same paper, with reference to the strength and the ductility of welds made with the three grades of welding rod. These are given in Table 2.

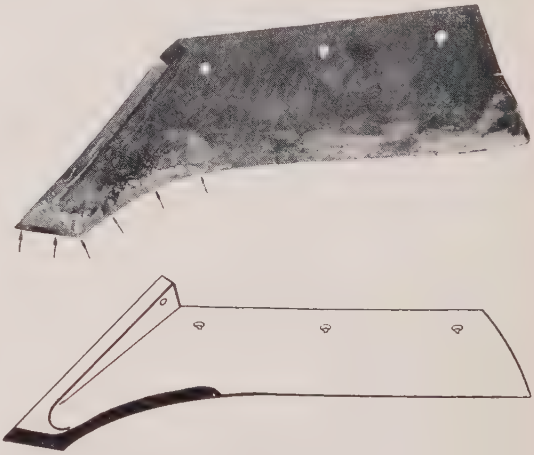


Figure 14—Photograph and Sketch Showing a Plow Share to Which Stoodite Has Been Applied to the Lower Side of the Share as Shown by the Arrows and the Shaded Area. No Hard Facing Metal Has Been Applied to the Top of the Share. When the Hard Facing Metal is Applied in this Manner, the Upper Side will Wear Away where the Softer Metal Comes in Contact with the Soil and a Sharp Cutting Edge will be the Result. The Sharp Edge will be the Hard Facing Metal, Which will Resist Abrasion to a Great Extent.

Another patent, granted July 3, 1923, to James H. Critchett, No. 1,460,790, includes seven claims covering a welding rod consisting of an iron alloy containing carbon and a substantial amount of chromium.

Based upon this patent, a rod has been developed which is used to a considerable extent upon the railroads for the building up of battered and worn rail ends. The addition of chromium to this alloy makes the weld hard, tough, and resistant to abrasion. The weld is self hardening, without subsequent heat treatment.

A large proportion of the low carbon steel welding rods upon the market are now made in accordance with the American Welding Society analysis G. No. 1 A. High carbon steel rods and nickel steel rods are also made by most companies producing welding rods, in accordance with the specifications of the American Welding Society. This society, however, has never seen fit to advocate an analysis, or a specification, for a welding rod of medium carbon grade for oxy-acetylene welding.

(See also later specifications described in Chapter 1, Part II.)

There are many welding rods known throughout the country, bearing trade names and of special analysis and manufacture. Most of these rods are excellent rods and serve their purpose satisfactorily. But the purpose of these lessons is to give the student as much information as possible about the subject discussed, and while the analysis of a welding rod does not entirely determine its qualities, it has a definite bearing upon them, and the student should know the approximate analysis of the rods which he is using in order that he may use them intelligently in the work which he has to do.

For this reason Table 3 is given showing the type of rod, the size in which it is ordinarily furnished, the general purpose of the rod and the analysis of the steel. Only those rods have been given, the analysis of which is known. The student would gain nothing if rods were included under trade names, the analysis of which was unknown.

Table 2

Tests of Welds*

Tensile Tests

Welding Rod	No. of Tests	Yield Point	Average Tensile Strength	Per Cent Elongation (2 in.)
Norway iron	5	38,500	51,600	10.2
Mild steel	5	39,000	50,300	8.4
"High test rod"	12	42,800	62,400	11.2

		Cold Bend Tests		*Hot Bend Tests*	
Rod	No. of Tests	Load, Lbs. Per Sq. In.	Angle of Bend	First Crack Angle Bend	When Bent Flat
Norway iron	8	9,500	63	135 deg.	Slight crack
Mild steel	5	10,850	28	100 deg.	Slight crack
"High test rod"	6	15,400	54	150 deg.	Very slight crack

**All welds in ½ in. thick plate with weld and plate machined to same thickness.*

Welding Manganese Steel

The jaws of stone crushers, the teeth of steam shovels, the lips of clam shell buckets and many other similar things are made of manganese steel. This steel usually contains from 1.0 to 1.4 per cent of carbon, from 11.00 to 14.00 per cent manganese, about 1.0 per cent silicon, 0.10 phosphorus, 0.05 sulphur. The phosphorus and the sulphur contents are the maximum content permissible as these elements are impurities. The tensile strength of manganese steel varies between 70,000 and 100,000 pounds per square inch and a one-half inch by three-quarter inch bar can be bent cold on the flat side around a rod having a diameter of one inch to an angle of 180 degrees.

When slowly cooled manganese steel is weak and very brittle, but when heated to a temperature of 1940 degrees Fahrenheit and suddenly chilled, either in water or cold brine, it becomes ductile and tough. It also has the quality of increasing in hardness due to repeated violent blows, such as it would be subjected to in a stone crusher or in connection with digging machinery.

After being heat treated at the factory by quenching it in water, the metal is hard but not nearly as hard as chilled iron or hardened steel, but when it is put in use and subjected to many repeated blows, it becomes very hard and tough and resists abrasion to a great extent. This quality of increasing in toughness and hardness as the metal is used is the quality which makes manganese steel so valuable for the purposes heretofore mentioned. It is obvious that steel possessing such qualities may present many obstacles if welding is attempted.

The welder may, however, be called upon from time to time to build up worn manganese steel parts of steam shovels, clam shell buckets, etc., or to build up manganese steel frogs, crossings, or switches and the extent of his success will depend largely upon the knowledge which he has of the peculiar characteristics of this metal. Welding manganese steel to make a weld possessing the strength of the original steel, or to make a weld which can be fairly considered a substitute for a new casting is very difficult with the oxy-acetylene process. Nickel, manganese steel electrodes, containing from 3 to 5% of nickel, enable the arc welder to produce fairly successful results provided the weld is made a little at a time and the casting is kept cool. *(See Chapter 6, Part II.)*

Manganese steel is used, to a considerable extent, in the manufacture of frogs, switches and crossings for railway tracks. It presents a very hard surface to the pounding of the wheels of traffic and will wear much longer than other steels. The street car companies use manganese inserts in crossings which can be noticed in many street car tracks if particular attention is given to the crossing. These manganese steel plates, constituting a part of the frog or crossing, drop into a recess provided for them and are removable when badly worn.

Manganese steel, to give the best results, must be placed in the right kind of service. Its resistance to ordinary abrasion is less than its resistance to repeated blows. For instance, if the teeth of a steam shovel are used for digging hard rock, the manganese steel will stand up for a very considerable period of time. If the shovel is to be used for digging sand, or fine quartz, the abrasion will wear the teeth down considerably in a very short time.

Manganese steel has another quality which prevents its use for certain purposes. At first it was thought that this steel would make excellent car wheels and quite a number of them were made and put into service. While it was found that the surface of the car wheel tread stood the wear of the rail to great advantage, the metal flowed at the sides and caused fins to extend on the inner sides of the wheels, ultimately resulting in abandoning the attempt to utilize manganese steel for this purpose. The repeated pounding of the surface of manganese steel will cause the metal to flow in some other direction and, while the surface is extremely hard, the casting may increase in dimensions where the metal is not subject to pounding.

Manganese steel, like steel containing twenty per cent or more of nickel, is non-magnetic. It is made by adding ferro manganese to low carbon steel usually produced in a Bessemer converter. It is also made from manganese steel scrap in electric furnaces.

There are several reasons why the fusion welding of manganese steel will not produce a weld having the strength normally required of a manganese steel casting. In the first place, the reheating of the toughened manganese steel to approximately 850 degrees Fahrenheit makes the metal brittle regardless of the rate at which the steel is cooled from this temperature. Therefore, surrounding every weld there is a zone or area of brittle metal. If the whole casting is heated to approximately 1940 degrees Fahrenheit and suddenly quenched in water, the brittleness will be eliminated. The melting point of manganese steel is approximately 2400 degrees Fahrenheit. Heating it to approximately 2200 degrees Fahrenheit causes true burning in similar manner to the burning of other high carbon steel. It may be reheated to 1940 degrees Fahrenheit and quenched in water, as previously described, but even this treatment does not restore its original qualities after it has been burned. For this reason most manganese steel welds fail, if subjected to too great strain, in the manganese steel immediately adjacent to the weld.

With the foregoing knowledge of the peculiar characteristics of manganese steel, the welder can without difficulty select that work which he believes should be welded without endangering the part. There are a great many worn manganese steel parts which can be welded, or built up, to very great advantage and with a tremendous saving. These parts consist of crusher jaws for crushing, screening and dredging plants, dredge cutting heads and blades, pump casings, dipper fronts and teeth and grab bucket lips. In the mines, smelters, furnaces, steel mills, railroads, etc., there are many parts made of manganese steel to resist wear which can be built up if the work is properly done.

It is essential, where possible, in making welds in manganese steel to follow the recommended practice given herewith and to use manganese steel welding rods of approximately the following analysis:

Carbon	1.00 to 1.45 per cent
Manganese	12.00 to 15.00 per cent
Silicon	0.10 to 0.20 per cent
Phosphorus	0.05 to 0.09 per cent (maximum)
Sulphur	0.01 to 0.03 per cent (maximum)

These rods are procurable in sizes from one-eighth to three-eighths inches in diameter and thirty-six inches in length.

A welder of manganese steel should bear in mind that cast manganese steel has a lower melting point and a higher expanding point than either carbon or alloy steels. It is, therefore, obvious that simple carbon or alloy welding rod should not be used in welding manganese steel castings. The fusion point of these rods is higher than the manganese steel casting, and the manganese steel is likely to be overheated if such rods are used.

The metal along a crack in a manganese steel casting should be veed out with the cutting torch to an included angle of ninety degrees. This steel cannot be cut with ordinary tools and the cutting torch is, therefore, essential for this purpose. The slag along the line of cut should be thoroughly cut away, and the metal left clean. A rough fire-brick furnace should then be built around the casting and charcoal or an oil preheater used to preheat the casting to a dull red heat.

The welding torch should be adjusted so that a slight excess of acetylene will be supplied to the flame. A neutral flame will burn away a considerable portion of the manganese during welding. If, on the other hand, too much acetylene is used, the hot steel will absorb carbon from the flame. A little experimental work with the flame will show exactly the right adjustment.

The weld should be made just as in other steel castings with the manganese steel rods and built up to a thickness greater than that of the wall of the casting to give the necessary added strength to it. When the weld is completed the casting should be placed in ashes or lime, or packed with asbestos, in the temporary fire-brick furnace and allowed to cool down very slowly. The entire casting after having been cooled should be reheated to a temperature of about 1940 degrees, nearly a light yellow heat, and maintained at this temperature for approximately one hour. The casting should then be quickly removed from the

Welding and Cutting in the Steel Foundry

Table 3

Analyses and Purposes of Various Types of Welding Rods

Rod No.	Type of Rod	Purpose of Rod	Analysis
1	Low Carbon Steel	For general repair work on ordinary steel where a good sound non-porous weld of high ductility is desired.	American Welding Society G-No. 1A Carbon 0.06 Max. Manganese 0.15 " Phorphorus 0.04 " Sulphur 0.04 " Silicon 0.08 "
2	Low Carbon Steel Carbon content slightly higher than Rod No. 1	For production work on mild steel such as boilers, tanks, pipe lines, etc., and also for same purposes as Rod No. 1. Welds produced are ductile, easily machinable and show a uniform high tensile strength.	Carbon 0.06-0.10 Manganese 0.35 Max. Phosphorus 0.04 " Sulphur 0.04 " Silicon 0.04 "
3	Medium Carbon Steel	Used principally for general railroad repair work where an easily machinable but less ductile weld than that made with Rods No. 1 and 2 is desired.	American Welding Society E-No. 1B Carbon 0.13-0.18 Manganese 0.40-0.60 Phosphorus 0.04 Max. Sulphur 0.04 " Silicon 0.06 "
4	High Carbon Steel	Largely used for building up frogs, crossings, rail ends, etc. The welds are not machinable and must be ground to a finish.	American Welding Society E-No. 1C Carbon 0.85-1.10 Manganese 0.30-0.60 Phosphorus 0.04 Max. Sulphur 0.04 "
5	Nickel Steel	The nickel content of the rod produces a weld of much higher tensile strength than can be obtained with an ordinary steel rod, but does not sacrifice machinability. To be recommended for jobs where the weld must be machined flush with a surface and yet show a high tensile strength.	American Welding Society Nickel 3.25-3.75 Carbon 0.15-0.25 Manganese 0.50-0.80 Phosphorus 0.04 Max. Sulphur 0.04 "
6	Chrome-Vanadium Steel	This alloy rod produces a very hard, tough weld of maximum tensile strength. It is self-hardening and offers maximum resistance to abrasive wear. For building up frogs, switches, rail ends, etc., it seems to withstand crystalization much better than a high carbon rod.	Chromium 0.80-1.10 Vanadium 0.15-0.18 Carbon 0.40-0.50 Manganese 0.50-0.80 Phosphorus 0.04 Max. Sulphur 0.04 "
7	Carbon-Manganese-Silicon Steel	This alloy rod produces a very strong weld. Used for pipe lines, boilers, tanks and other welds where additional strength is required.	No. 1 High Test. Patent No. 1,452,781 Carbon 0.20 Manganese 0.80 Silicon 0.55
8	Carbon-Chromium Steel	Used for building up frogs, switches, crossings and rail ends in maintenance of track work.	Crichett Patent No. 1,460,790. Claim 7 Carbon 0.50 Chromium 1.1
9	Vanadium Steel	Used for welds requiring additional strength and toughness.	Carbon 0.09-0.14 Manganese 0.20 Max. Phosphorus 0.03 " Sulphur 0.03 " Silicon 0.20 " Vanadium 0.15 "
10	Manganese Steel	Building up worn manganese steel frogs, switches and crossings. Also crusher and digging machinery teeth and parts.	Carbon 1.00-1.45 Manganese 12.00-15.00 Silicon 0.10-0.20 Phosphorus 0.05-0.09 Sulphur 0.01-0.03

Note: All of the above rods can usually be obtained in the following diameters and in 36-inch lengths: $\frac{1}{16}$ inch, $\frac{3}{32}$ inch, ⅛ inch, $\frac{5}{32}$ inch, $\frac{3}{16}$ inch and ¼ inch.

furnace and suddenly plunged into a bath of cold water, or cold brine. Such treatment will develop toughness, resistance to wear and tensile strength of the casting. Manganese steel castings may be hammered if desired, but the hammering should be done when the steel is cold.

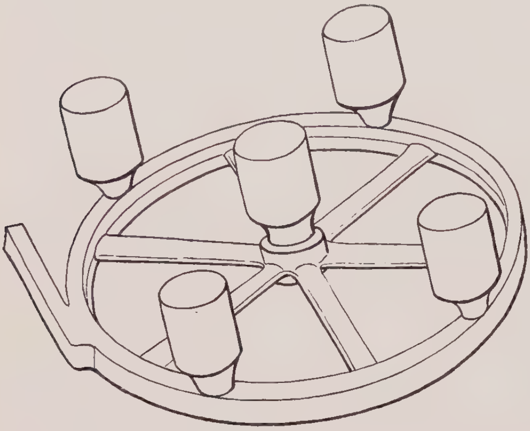


Figure 15—Sketch Showing Five Risers and a Runner Upon a Cast Steel Wheel. Four of the Risers have Fed the Rim and One the Hub of this Casting.

Cutting Manganese Steel

It will now be appreciated that when manganese steel is welded the weld cannot be finished except by grinding. This is also true of the unwelded portion. One of the characteristics of manganese steel is its toughness. It is so tough that ordinary machine tools will not cut it on a commercial scale. The only manner, therefore, in which it can be cut commercially is with the oxy-acetylene torch. There are many manganese steel castings made daily upon which the risers must be cut from the casting with a torch. It would be practically impossible to cut them in any other manner.

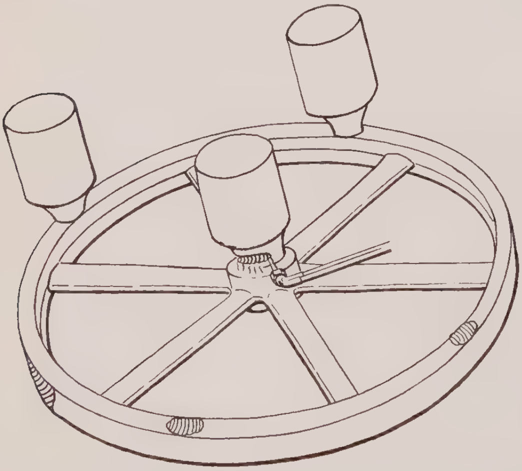


Figure 16—Sketch Showing the Procedure in Cutting Off the Riser from the Hub of the Wheel Two Risers have been Cut from the Rim and the Runner has also been Cut Away.

When manganese steel parts are used for machinery it becomes necessary at times to cut or trim away these parts during fabrication The cutting torch is essential for this work. More and more manganese steel finds its way into the scrap yard and it would be impossible to utilize it at all if it were not for the cutting torch. Manganese steel cuts readily and no specific instructions are necessary in connection with it, but the very great value of the cutting torch for cutting manganese steel which cannot be cut in any other way, should be emphasized.

Welding and Cutting in the Steel Foundry

The filling up of blow holes, or sand holes, in steel castings is the principle use for the welding torch in the steel foundry. Much of this work is done, under present conditions, with the electric arc, because of the fact that no preheating is necessary when the arc is used and the expense of welding is correspondingly less. The quality of the weld for such work is not material, because in most instances, the defects in steel castings are in heavy sections where the part is amply strong in spite of the defect. Welding is applied only to fill up the defect for the sake of appearance and not for the sake of strength. The hardness of such a weld is often immaterial, because the casting is not finished or machined after the weld is made and any little roughness of the surface can be cleaned up with a grinding wheel. For this reason, refinements in welding are unnecessary, and the least expensive weld usually suffices.

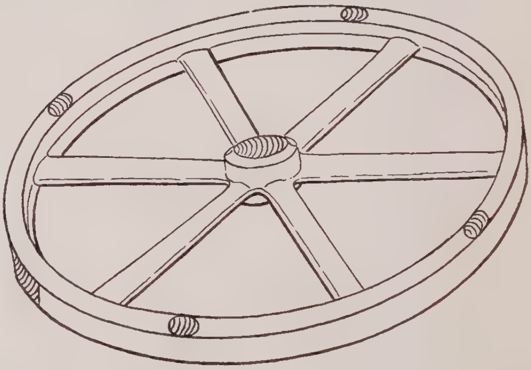


Figure 17—Sketch showing the Cast Steel Wheel After the Risers and the Runner have been Cut off with the Cutting Torch.

For cutting the risers, runners, sprues, etc., from steel castings, however, the cutting torch has no equal. A riser is a large cylindrical projection of excess metal placed in the casting at suitable locations by making similar openings in the molds.

The reason for placing risers upon castings may not be obvious to the student and a few words in this connection will make the matter clear. Castings shrink as they cool and thus would normally occupy less space when solid than when the metal was molten. If there were not some pressure upon the metal, or if there were not some means to feed more molten metal to the

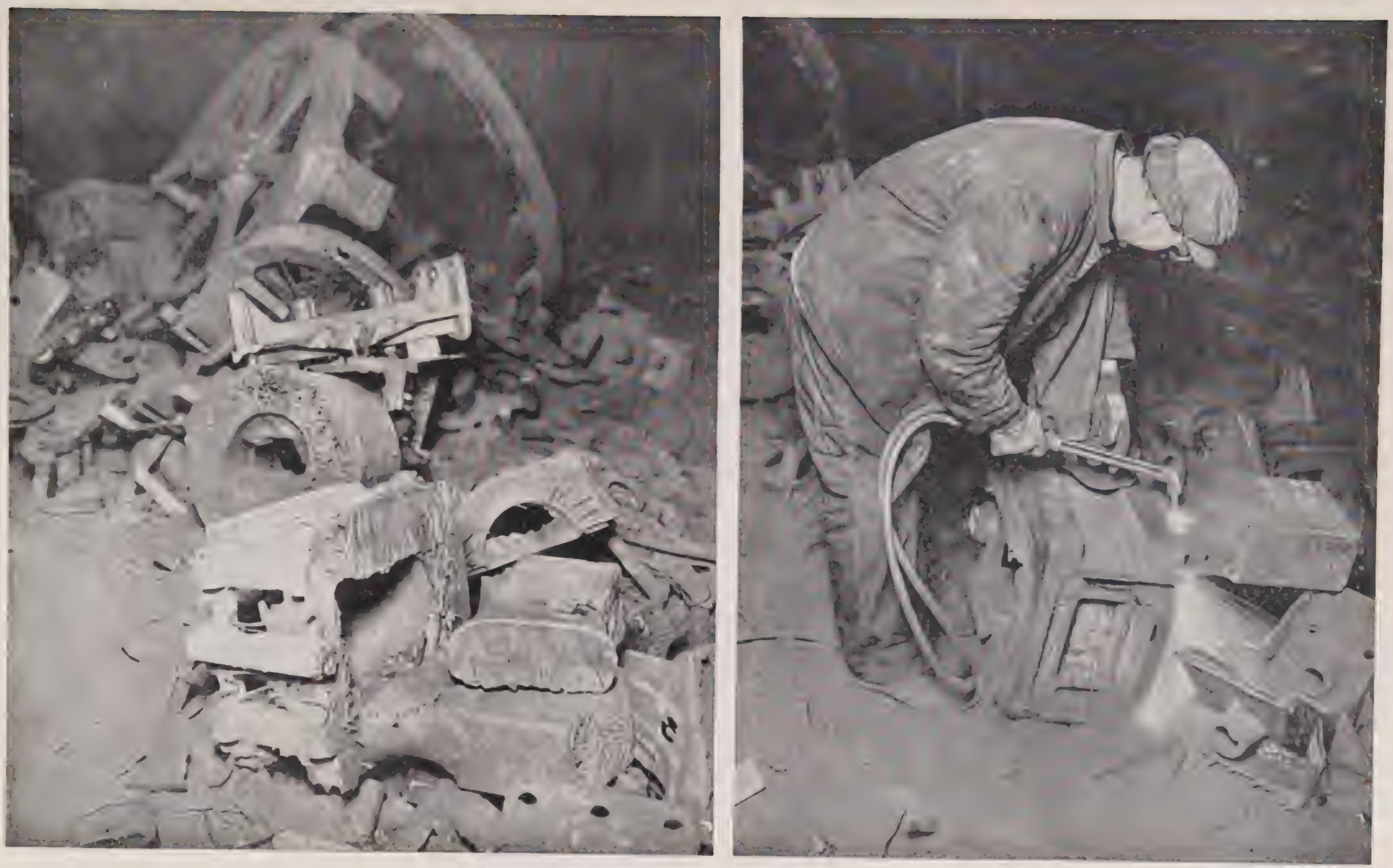


Figure 18—These Two Photographs Illustrate a Pile of Castings in a Steel Foundry, As They Are Usually Found Ready for the Operator Who Cuts the Risers from Them, and the Operator Cutting One of These Risers. The Riser Shown in the Left Hand Illustration, Which Has Been Cut from the Casting, Is About Five Inches Thick and Twelve Inches Wide. The Photograph to the Right Shows the Actual Cutting of This Riser. The Advantage of Piling Castings in Assorted Piles Based Upon the Thickness of the Risers Will Be Readily Appreciated.

casting as cooling takes place, there would be a part of the mold which would not be completely full and this would mean either a smaller cross section at this point, or a hollow space within the casting. In order to relieve this situation, risers or heads are placed at suitable points in the mold, so that they may act as reservoirs to feed additional molten metal to the casting where required and to increase the pressure of the metal in the mold.

The size of the head of the riser is, therefore, very important and the location of the riser upon the casting is also a matter requiring careful design. Just above the casting the riser is "necked" to a smaller cross section than its head, so that it may be removed or cut away with the torch with greater facility. Removal of risers is one of the operations in a steel foundry involving considerable expense and the method of "necking" the riser and cutting risers with the torch is a matter requiring careful attention to keep this expense as low as possible. Figure 15 shows a large cast steel wheel, having five risers, four upon the rim and one upon the hub at the center. To the left of the rim a runner is shown, connecting the rim with a source of supply of the metal, or with another similar casting.

In Figure 16 the cutting torch is shown cutting the riser from the hub of the wheel. Each riser and the runner is respectively cut from the casting with the result that the casting is quickly freed of these obstructions, as shown in Figure 17. Of course, the place where each riser was cut away must be ground down if required with a flexible shaft grinding wheel, thereby completing the rough casting.

It is interesting to know, in connection with the cutting of risers, the length of time required and the oxygen and acetylene consumed per square inch of riser cut. With such figures available, it is very easy to determine, by the dimensions of the riser required to be cut, how much gas and time is necessary to accomplish the work. The following figures have been determined from a very careful test made in a large steel foundry, during which about 260 risers were cut, the largest of which was fourteen inches by six inches and the smallest two inches by one and one-half inches. This was a general run of risers, and not a selected few, and represents the actual cost of cutting risers in a steel foundry when they are cut just as they are dropped by the crane. These figures give the gas cost only. The labor cost is an indefinite quantity, depending to a large extent upon the amount of wasted time of the cutter caused by delay of delivery of the castings where they can be cut, or by delay in moving castings from a pile in such manner that the cutter can get at them.

The average of these figures showed that it required four-tenths of a cubic foot of oxygen for each square inch of riser cut and that the proportion of oxygen to acetylene was six of oxygen to one of acetylene. If oxygen is assumed to cost one and one-half cents per cubic foot and acetylene, generated in an acetylene generator, one and one-quarter cents per cubic foot, the gas cost per square inch of riser cut would be 0.69 cents. The labor cost would be, of course, in addition to this.

The average speed of cutting risers with the oxy-acetylene torch, taken from actual practice in one steel foundry, is approximately eleven seconds per square inch of cut. This includes the time required for a casting, such as illustrated in Figure 15, of starting the cut upon one riser, completing that cut and beginning a cut upon the second riser, etc. There is, of course, an appreciable amount of lost time in starting the cut upon the second or third riser and this varies to a considerable extent, depending upon the condition of the surface, the amount of sand which adheres to the casting and the accessibility of the cut.

The size of the risers, of course, has a direct bearing upon the speed of cutting. Small risers require considerably more time to cut per square inch than larger risers. It is good practice to segregate steel castings in the steel foundry into piles. The small risers, approximately two to four inches in thickness, might be placed in one pile; those from four to eight inches in another pile; and those from eight inches and upward in a third pile. In such cases the risers are usually cut by different men, each equipped with a torch and the right size tip for the pile of risers in question. In this manner changing of tips and pressures is less frequent and the man becomes more skilled in doing the class of cutting required of him.

Welding Cutter Bars

Many mowers have been made with malleable cast iron knife heads. In the more modern machines the manufacturers have replaced this malleable cast iron part with one made of drop forged steel. Figure 19 shows a malleable cast iron knife head attached with rivets to some of the knives on the cutter bar. On the opposite side of these triangular knives there is a five-eighths inch by three-sixteenth inch steel bar riveted through the blade and the knife head. This bar is shown in Figure 20. A break often occurs in the bar where indicated by the arrow and a very satisfactory method of repair is described and illustrated herewith.

The edges of the broken bar should be bevelled and the rivet hole enlarged with the cutting torch. Breaks almost always occur through the rivet holes. The two ends of the bar with the rivet slipped through the malleable iron knife head and through the blade should then be placed in position and lined up accurately with the rest of the bar. The break in the bar and the end of the rivet should then be welded solidly in one weld. For a job of this kind it is good practice to use vanadium steel welding rods. These have been heretofore described and will produce a tougher, stronger weld than one made with welding rods of low carbon steel.

It does not make a great deal of difference if the nearest blade of the knife is heated, because at this end of the bar the three or four blades are not required to do any cutting. After the weld has been made the rivet head shown by the arrow in Figure 19 will be found loose and must be riveted tight by placing the cutter bar on an anvil.

This is one of many such repairs which can be made to farm machinery. A little ingenuity is sometimes required to make these repairs efficiently and economically, but they do not present any very difficult problems. Of course, some of the parts, particularly those manufactured of steel, are likely to be of heat-treated alloy steel and in this event, care must be taken to prevent the heat of the torch from injuring the heat-treated part, more than is absolutely necessary. Proper reinforcement must be made where required in welding heat-treated steel, as has been heretofore described.

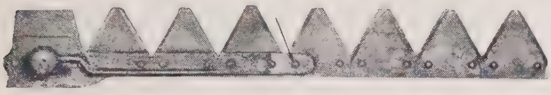


Figure 19—Photograph of Parts of a Cutter Bar of a Farm Mower. This Side of the Cutter Bar Shows the Malleable Iron Knife Head.

Terms Commonly Used in Reference to the Strength of Steel

Before closing the lessons on steel, it is believed that a few remarks pertaining to the common terms used by engineers and technical men with reference to the strength, elasticity, elongation, etc., of steel would be of much value to the student. It will be endeavored to explain these terms in as simple words as possible, so that the explanations will be clearly understood.

Tensile Strength—The tensile strength of a steel bar is its resistance to being pulled apart if a pull is applied to each end of the bar. The tensile strength is usually measured in pounds per square inch of cross section of the bar. A bar, for instance, measuring one inch square may have a tensile strength of approximately 50,000 pounds. If the bar is round instead of square, it would be one and one-eighth inches in diameter if the cross section were one square inch. Therefore, a round bar, of similar steel, one and one-eighth inches in diameter, would also have a tensile strength of approximately 50,000 pounds.

Stress—The stress in the bar is the internal force resisting the attempt to pull it apart.

Strain—A strain is the elongation, or change produced in the shape of the bar by the load applied to it. For instance, if a bar were supported at its upper end and a weight of 25,000 pounds attached to its lower end, the steel of the bar would stretch a given amount. The amount of this stretch is called a strain.

Elastic Limit—If a bar is supported at one end and a weight attached to its lower end, as stated above, it will be strained or will stretch a given amount. When the weight is removed the bar will return to its original length. If the weight is increased, however, up to a certain amount, the bar will be permanently stretched and will not return to its original length when the weight is removed. This point is called the elastic limit of the metal. This is the force, usually measured in pounds per square inch, necessary to produce the first permanent set in the metal.

Percentage of Elongation—When a steel bar has been loaded up to its elastic limit it will begin to stretch permanently. As the load is increased it will continue to stretch until it finally breaks. A low carbon steel or, for instance, a metal like copper may stretch out to nearly twice its original length before breaking. The increase in length, divided by the original length, is called the percentage of elongation. In testing steel bars it is often measured in a length of two inches and perhaps more frequently in a length of eight inches.

Reduction of Area—As the bar elongates it, of course, is reduced in cross section. Just before the break occurs the cross section of the bar is still further reduced on each side of and immediately adjacent the break. The original area minus the smallest area adjacent the break is called the reduction of area. This amount divided by the original area is called the percentage of reduction of area.

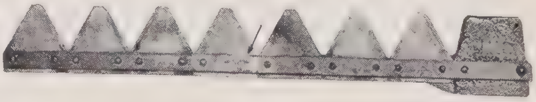


Figure 20—This Photograph Illustrates the Opposite Side of the Cutter Bar Shown in Figure 19 Where the Break Occurred in the Steel Bar Riveted to the Triangular Knife Blade. The Break is Indicated by the Arrow. The Two Ends of the Broken Steel Bar and the Rivet Projecting Through the Hole at this Point were all Welded Together.

Ductility—The ductility of a metal is that property which permits it to stretch or bend.

Compressive Strength — The resistance to crushing of a metal is called its compressive strength. It is measured, as a rule, in pounds per square inch.

Transverse Strength—The transverse strength of a bar is its resistance to bending when supported at each end upon sharp supports with the force applied in the center of the bar in a downward direction.

Shearing Strength—If the bar were placed in large shears, its resistance to being cut with these shears would represent its shearing strength.

Torsion—If the bar is placed in a large machine, which will twist it, its resistance to twisting is called the torsional strength of the bar. The number of times the bar may be twisted without breaking gives an indication of its ductility under this kind of stress.

Toughness—The toughness of a metal is that quality which enables it to resist breaking even though subjected to repeated loads and much deformation.

Brittleness—If after the elastic limit of a metal has been reached it breaks quickly and with ease it is said to be brittle. For instance, the elastic limit and the ultimate tensile strength of a very brittle steel will be almost equal.

Malleability—When a metal is hammered its shape can be changed to a new and different shape. This quality of the metal is called its malleability. For instance, gold is the most malleable of the metals and can be hammered out to a very thin sheet without cracking.

There are, of course, many other terms and expressions used in connection with steel, but these are the ones which will be most commonly encountered by the welder and with which he should be more or less familiar.

Job Sheet No. 10

Welding a Steel Test Bar.

Job Sheet No. 10 is, in reality, an examination to determine whether or not a student has become proficient in the welding of steel. The work called for consists of welding together two pieces of steel three-eighths inch thick, two inches wide and six inches long, to form a bar three-eighths inch thick by two inches wide by twelve inches long. This weld should be made according to the method learned by the student in the previous lessons of this course.

The material used should preferably be new and unused steel of a good quality. The pieces should be cut to exact size and the ends carefully bevelled in the manner already described in previous lessons. The welding should be the best that the student is capable of performing. After welding, the pieces should be allowed to cool naturally and should not be quenched in water or oil.

After the two pieces are welded together, they may be sent to the nearest university where, as a rule, the testing department will test the bars for a small charge.

It is extremely important that each student weld his own test bar. If he cannot have it tested for tensile strength at a university, he can bend it in a vise to an angle of 180 degrees as shown in Lesson 13, page 195, which will give him an excellent idea of its strength.

Questions:

1. Make a rough sketch showing the manner in which you would repair a jagged tear about six inches long in the door of an automobile body.
2. What is the purpose of an alloy rod, similar to Stoodite or Stellite?
3. What purpose do the hook-bolts, shown in Figure 13, serve?
4. What is the most valuable physical property of manganese steel?
5. What is a riser?
6. Why is hard-facing metal applied only to one side of a plow share?
7. What effect does the carbon content have upon the melting point of steel?
8. Make a rough sketch showing the complete construction of a templet that would be used for cutting two pieces of two and one-half inch steel shafting to be welded together so that the angle between these pieces would be seventy-five degrees. Give the exact length of the base line of this templet.
9. How should manganese steel be treated after welding?
10. What is the principal advantage of using a cutting torch for removing the risers from steel castings, rather than a metal saw?

Lesson No. 11

Bronze Welding Cast Iron

THE welding of cast iron parts involves a good many considerations which need not be taken into account when welding steel. When heated, cast iron will expand slightly less than either steel or wrought iron, but steel will stretch and distort to a considerable extent when contraction takes place as the metal cools, while cast iron will stretch so little that, if it is strained too much, it will break. For this reason the problems encountered in welding cast iron differ from those found in welding steel and the effect of expansion and contraction becomes much more important.

In the early days of the welding process, it was considered essential to weld cast iron by making fusion welds and melting into the welds cast iron rods containing about three per cent of silicon. Silicon in the welding rods promotes the precipitation of graphite, as described later in this lesson. Without this amount of silicon present, most of the carbon content of the iron would be in the combined form and the weld would be hard.

The expansion of the metal, in fusion welds, was so great that subsequent contraction strains would often cause the welds to break, when welds were attempted without preheating the piece. For this reason, preheating became common practice and it was considered necessary to preheat all heavy or intricate iron castings before welding. A further reason for preheating was the fact that cast iron becomes hard when cooled rapidly and in many cases, where machining was required, it was essential that the weld be as soft as possible, in order not to interfere with subsequent operations.

Bronze Welding Rods

The difficulty of preheating and its cost led to the use of bronze as a filling rod, and, as the process developed, bronze welding became more and more popular for the welding of cast iron parts. Tobin bronze is an alloy commonly used for welding rods for bronze welding cast iron. The melting point of Tobin bronze is about 1625 degrees Fahrenheit, while the melting point of cast iron is 2300 degrees. It is not necessary, therefore, to melt the cast iron to fuse and flow the melted bronze over the iron surface. It is only necessary to heat the iron to a cherry red heat, shown at No. 5 Chart No. 6, Lesson No. 7, in order to flow the molten bronze upon the surface. When the iron is clean and the bronze is not overheated, the bronze will cling to the iron with great tenacity and the joint will have a strength greater than that of the iron itself.

The details of this process will be discussed later in this lesson after the metal, cast iron, has been studied and its characteristics fully understood. Because bronze welding requires no preheating of the casting itself, except under unusual conditions, and because bronze welding can be accomplished more quickly and with less expense than cast iron welding, the former process has become very popular with welders for the repairing of many broken castings. For this reason, the first lesson on cast iron welding is devoted to the bronze welding of cast iron rather than to welding cast iron by the fusion process.

Characteristics of Cast Iron

Heretofore, in these lessons, steel only has been considered. The manufacture of steel has not been given much consideration because of the fact that such a study is really a subject in itself and it has not been possible to give the necessary time and space to it in these lessons.

Short definitions, however, of wrought iron, steel and cast iron will perhaps help the student to understand more fully the differences between these metals. Wrought iron is low carbon iron which has been produced in a pasty condition in a puddling furnace. It is made from white hot balls of metal, which are squeezed and worked, and for this reason has considerable slag interspersed throughout its entire body. It is supposed that the slag envelopes the grains of the metal, and this condition is believed by many to give it a greater resistance to corrosion and rust. For instance, pipe made of wrought iron is said to resist rusting to a greater extent than pipe made from steel.

Steel is iron, usually containing less than one and one-half per cent of carbon, which is produced in a fluid state in several types of furnaces. It contains less carbon than cast iron and because of the method of its manufacture from a liquid, and not from a pasty ball, the slag is almost entirely removed.

Cast iron contains more carbon than steel, usually about three and one-half or three and three-fourths per cent, and more impurities such as silicon and phosphorus and occasionally sulphur and manganese. The characteristics of cast iron are due almost entirely to its impurities, the most important of which is graphite.

When cast iron cools very slowly a part of the carbon, for the strongest iron two and three-fourths per cent, precipitates as graphite and leaves approximately one per cent in the form of combined carbon. Combined carbon is that portion of the carbon which does not precipitate as graphite, but which remains combined with pure iron in the form of cementite, or iron carbide. Cementite is very hard and brittle and the amount of it present in cast iron controls to a large extent the hardness of the metal.

This subject is rather an involved one, but put in a few simple words it can be readily understood. If molten iron is cooled slowly a considerable portion of the carbon contained in the iron will be precipitated in the form of graphite flakes, and the result will be what is commonly called grey iron. This iron is soft and easily machined, but has less tensile strength than steel. The reason for its lack of strength lies in the fact that the graphite flakes have little strength and these are interspersed throughout the iron.

Fracture of the iron usually takes place by breaking the graphite flakes apart. This accounts for the grey color of the fracture and from this color its name is derived. If a newly broken piece of grey iron is cleaned thoroughly with a wire brush the fracture will become silvery white in color, indicating the color of the metal itself rather than of the flakes of graphite.

On the other hand, if cast iron is cooled rapidly, the proportion of the carbon which precipitates as graphite flakes, is very much less and the greater part of the carbon remains combined with the pure iron in the form of cementite. The iron is thus made hard and brittle and becomes what is called white cast iron. This characteristic is taken advantage of in the manufacture of chilled castings. When molten cast iron is poured into a cold cast iron mold, the surface of the metal next to the chilling mold becomes hard white iron, with a large percentage of cementite and very little graphite. The interior of the casting, which has been allowed to cool more slowly, is grey iron and has its usual characteristics, if sufficient time in cooling has permitted the carbon to precipitate in the form of graphite flakes.

It may seem to the welder that this discussion does not seriously affect him, but as a matter of fact, it explains why so many welds are hard and not machinable. Many welders have blamed all sorts of causes for their apparent lack of ability to make soft welds. These causes included both the torch and the welding rod where perhaps neither were responsible for the results.

Fusion Welding Requires Preheating

When a fusion weld is to be made in an iron casting, it is necessary to expand equally all parts of the casting to prevent strains in the metal, which would be set up from unequal expansion. The usual procedure to accomplish this purpose is to place the casting, after the crack has been prepared for welding, on the floor resting upon several bricks, or upon a fire-brick platform raised above the floor to a convenient height.

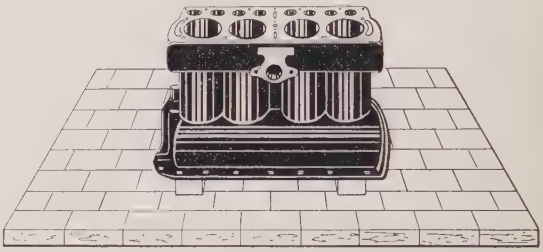


Figure 1—Sketch Showing a cast Iron Cylinder Block Set on Fire-brick Preparatory to Building the Rough Fire-brick Walls of a Furnace. Fire-brick Are Laid Over the Floor of the Shop to Form the Floor of the Furnace and the Cylinder Block Supported Underneath with Fire-brick so That There Will Be no Possibility of Warping or Sagging of the Casting.

A rough fire-brick wall is built around the casting leaving several holes at the bottom of the wall to admit air for draft. The furnace thus made is partly filled with charcoal and the charcoal lighted with a torch. Charcoal burns with a soft, even heat which will not injure the casting. More charcoal is added to the fire until it burns up brightly and a piece of asbestos paper, with a hole torn in it to let out the gases, is placed over the top of the furnace. In this way the casting is gradually and evenly heated throughout its entire body until it is a dull red.

A large hole is then torn in the asbestos paper, immediately over the crack in the casting and fusion welding is accomplished, using the torch, some flux and cast iron welding rods. When the weld is accomplished, more charcoal is added to the fire and the temperature again raised to an even heat. The furnace is then covered with asbestos paper, paper is placed over all of the holes and the casting allowed to cool in the dying fire, which often requires all night or all day, depending upon when the weld was made.

If preheating were not practiced and the torch were applied directly to the cold casting, thus raising the metal surrounding the crack to the melting point, the effect would be expansion immediately adjacent the melted metal in the area to be welded. The remainder of the casting would be relatively cool. Unequal expansion would be certain to result and internal strains might cause the casting to break while it was being heated. Contraction strains, as the casting cooled down, might cause the metal to break, either in the weld, or at some other point near the weld, where the section had less strength.

Rate of Cooling Is Very Important

At the lower temperature of a cherry red, to which castings are heated in bronze welding, little change takes place in the metal. When the temperature is raised with the torch to the point of fusion, and the metal subsequently cooled from a liquid to a solid state, the characteristics of the iron will depend to a very large extent upon the rate of cooling. If the casting is exposed to cold air and drafts, it will cool rapidly and a large part of the carbon in the weld will remain combined with the pure iron as cementite and the weld will be hard. If on the other hand the casting is covered with asbestos paper, lime, or enclosed in a rough brick furnace so that it will cool very slowly, the carbon in the weld will have time to precipitate as graphite flakes with the result that the weld will be soft, uniform and easy to machine.

The condition of the weld, therefore, is one which can be controlled by care on the part of the welder. The casting must be preheated slowly to equalize the strains of expansion, and must likewise be cooled slowly to prevent the formation of white iron and hard unmachinable welds. Such requirements necessitate several hours of preheating and sometimes twelve or fourteen hours for cooling with the result that fusion welding of iron castings is a slow process at best when the work is carried on properly.

Welding Cast Iron with Bronze

Although heating cast iron to the point of fusion involves a number of complications as just described, heating the casting to a cherry red does not seriously affect the characteristics of the iron and if the heat is properly applied, expansion will not present any serious problems. At this heat, somewhat below the fusion point of bronze, about 1,625 degrees Fahrenheit, the bronze can be melted with the torch upon the surface of the cast iron and will adhere to it when cooled with great tenacity.

The reasons given for this peculiar characteristic of bronze when applied to cast iron were presented in a paper read before the International Acetylene Association in Chicago, November 18, 1925, by Mr. Arthur R. Lytle. This paper described a very interesting study of specimens of cast iron, welded with bronze, in which it was shown under the microscope that the bronze actually penetrated the surface of the cast iron, displacing certain other compounds and forming minute roots, which made the union between the metals even stronger than the iron itself.

The condition of the surface of the cast iron is, however, a matter of much importance in bronze welding. The surface must be clean, free from rust, grease, dirt and scale. A rough surface is better than a smooth one, and one which has been ground or machined presents greater difficulty than other methods of preparation. Machined or ground surfaces are extremely difficult to tin with the bronze and the adhesion to them is poor. This is apparently due to the graphite flakes which are exposed by the machining operation or the grinding wheel. The difficulty, however, can be overcome by sand blasting, or by annealling the surface to a bright red. After this has been done, coating the surface with bronze and making it adhere in a satisfactory manner it is a very simple process.

Welding shops are not often equipped with sand blasting apparatus and annealing the surface to a bright red is not always possible. The torch may be used, however, to sear the surface, by passing the luminous cone of flame close to the surface to burn the graphite from the weld areas. A little practice will enable the welder to treat the surface skillfully in this manner. Cast iron pipe which has been correctly bevelled for welding may now be obtained from the manufacturers with the ends annealled for bronze welding.

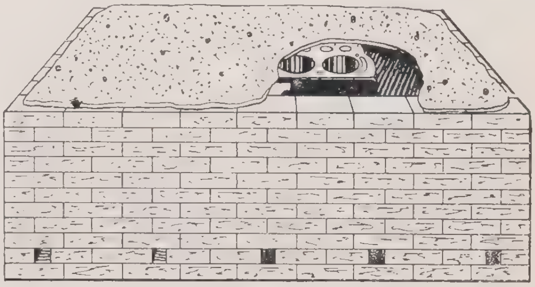


Figure 2—Sketch Showing the Completed Fire-brick Furnace with a Portion of the Asbestos Paper Cover Torn Away to Show the Casting. The Holes at the Bottom of the Walls are Left to Supply Draft and a Hole is Always Torn in the Asbestos Paper Cover to Permit the Escape of Gases. If Possible, Welding Should be Done Without Removing the Casting from the Furnace.

The expression, bronze welding, may be confusing to the welder, because in his mind welding normally means the fusion of both the part being welded and the welding rod. In bronze welding the piece being welded is not fused, and this is the important likeness of bronze welding to the process which in former years was called brazing. Bronze welding is in reality, brazing, but the industry has applied the new name because of the method of application in using a torch and bronze welding rods. Brazing was done with a large fire, or city gas or oil preheating torches, and spelter in granulated form.

While the principles of bronze welding did not differ materially from the old principles of brazing, the method of application was new and, therefore, a new name was given to it.

The application of bronze welding to repairing various cast iron parts has grown to a tremendous extent all over the country in the last few years. For instance, many cracked automobile cylinder blocks may be bronze welded to much greater advantage than by the old method of using cast iron and preheating the block. Preheating the block, of course, meant dismantling the engine entirely, removing the block from the chassis, building a fire-brick preheating furnace around the block and heating it all over to a dull red, either with charcoal or with preheating torches. In such instances, welding was accomplished with cast iron welding rods and a cast iron flux and the casting allowed to cool very slowly with the dying fire completely surrounded with fire-brick and asbestos paper.

The method of bronze welding is entirely different. It may, or may not, be necessary to completely dismantle the engine, depending upon the location and nature of the break. In some specific instances it may, of course, be necessary to preheat the casting, particularly if the break is in a location where local heat is likely to cause difficulty, but in many instances, a bronze weld can be made without complete dismantling and without preheating.

Melting Points of Welding Rods

Material	Approximate Melting Point—Degrees F.	Approximate Tensile Strength—Lbs. Per Square Inch Annealed Rods
Tobin Bronze	1625	54,000
Manganese Bronze	1598	60,000
Phosphor Bronze	1922	45,000
Brazing Metal	1634	50,000
Silicon Copper	1981	31,000
Electrolytic Copper	1981	30,000
Everdur	1866	65,000
Naval	1625	54,000

There are available to the welder at the present time a number of good bronze welding rods manufactured in diameters from three-thirty-seconds inches to three-eighth inches and in thirty six inch lengths, particularly for bronze welding. A brand of rods used to a very large extent for bronze welding is called "Anaconda" and is manufactured by the American Brass Co. The melting points, tensile strengths, weights per foot and the number of feet per pound of these welding rods are given in the tables to be found in this lesson.

Insofar as the bronze welding of cast iron is concerned, it is only necessary to consider Tobin Bronze, because this bronze has been found more satisfactory for the purpose than any of the other alloys. It is malleable, of high tensile strength and of uniform composition. It flows readily at welding temperatures and is easy to machine or finish. It is a copper zinc, tin alloy, containing about sixty per cent of copper, thirty-nine per cent of zinc, and one per cent of tin. Its tensile strength is approximately 54,000 pounds per square inch, while the tensile strength of cast iron is about 20,000 pounds per square inch.

Weight per Foot in Pounds of Round Welding Rods

Diameter	3/32"	1/8"	5/32"	3/16"	1/4"	5/16"	3/8"
Tobin Bronze	.02515	.04471	.06986	.1006	.1788	.2794	.4024
Manganese Bronze	.02503	.04450	.06954	.1001	.1780	.2781	.4005
Phosphor Bronze	.02658	.04726	.07384	.1063	.1890	.2954	.4253
Brazing Metal	.02514	.04469	.06983	.1006	.1788	.2793	.4022
Silicon Copper	.02639	.04692	.07331	.1056	.1877	.2932	.4223
Electrolytic Copper	.02663	.04734	.07398	.1065	.1894	.2959	.4261
Everdur	.02530	.04511	.07041	.10121	.18006	.28127	.4048
Naval	.02515	.04471	.06986	.1006	.1788	.2794	.4024

One of the principal things which the average welder must learn when he begins to bronze weld is that he cannot use the torch flame as he does in making the ordinary steel weld. If he tries to do this, he is certain to burn the bronze and to make a poor, weak weld. It is, therefore, necessary to manipulate the flame in quite a different manner. In the first place, the casting should be thoroughly cleaned adjacent the weld area. Scale, rust and grease should be removed from the metal for at least one inch back from the edges to be welded. The weld area should be finished by chipping and not by grinding, because the bronze will adhere better to the rough chipped surface. If a crack in a thin section of cast iron is to be welded, the crack should be chipped out with a round-nosed chisel, making a groove two-

Feet per Pound of Round Welding Rods

Diameter	3/32"	1/8"	5/32"	3/16"	1/4"	5/16"	3/8"
Tobin Bronze	39.76	22.37	14.31	9.940	5.593	3.579	2.485
Manganese Bronze	39.95	22.47	14.38	9.990	5.618	3.596	2.497
Phosphor Bronze	37.62	21.16	13.54	9.407	5.291	3.385	2.351
Brazing Metal	39.78	22.38	14.32	9.940	5.593	3.580	2.486
Silicon Copper	37.89	21.31	13.64	9.470	5.328	3.411	2.368
Electrolytic Copper	37.55	21.12	13.52	9.390	5.280	3.380	2.347
Everdur	39.53	22.17	14.20	9.881	5.555	3.555	2.445
Naval	39.76	22.37	14.31	9.940	5.593	3.579	2.485

thirds the thickness of the metal, and the corners of the groove should be bevelled off. When the crack is long an occasional cross groove from one to two inches in length should be made.

When heavier cast iron sections are to be welded, the edges of the break should be chamfered three-quarters of the thickness of the metal. This will leave one-quarter of the surface of the break to be fitted together. If the break is in steel, the full thickness of the metal should be chamfered or veed out wide enough to permit welding at the bottom of the vee.

A good brazing flux is necessary. The flux will materially assist in cleaning a weld and in reducing the oxide formed. A good bronze weld cannot be made with poor flux, and it is just as essential to use a thoroughly good flux as it is to use a good rod, or take pains with the work in any other manner.

In welding a neutral flame should be used. Some welders will advocate using a carbonizing flame, that is one having an excess of acetylene. It is believed that the use of a neutral flame is far better practice. The excess of acetylene in the carbonizing flame will lower the flame temperature somewhat, but has the disadvantage of delivering too much carbon adjacent to the hot metal. It is better practice to hold the torch away from the metal to control the heat, rather than to attempt to alter the flame.

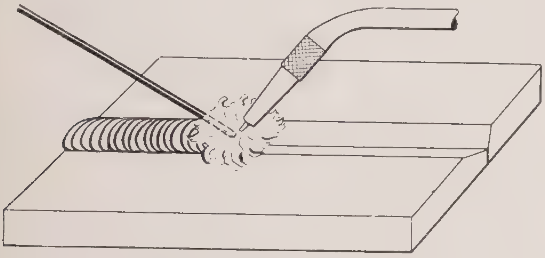


Figure 3—Sketch Showing the Torch and the Rod Held as in Fusion Welding. Bronze Welding Should Not Be Done in this Manner. The Luminous Cone of Flame in this Position would Burn Both the Rod and that Portion of the Bronze Weld Which has been Completed.

Reference to the illustration, Figure 5, page 17, Lesson No. 2, shows the temperature at the end of the luminous cone of the flame to be 6,300 degrees Fahrenheit. Approximately half way along the envelope of the flame the temperature is 3,800 degrees, while at the tip of the envelope the temperature is 2,300 degrees. The heat can, therefore, be controlled to better advantage by using the envelope of the flame which has sufficient variation in temperature to produce almost any degree of heat required, if the torch is properly held.

A small section of the area welded should be heated to a cherry red heat. The correct heat can be determined by warming up the end of the bronze rod and dipping it into the box of flux. In the meantime, the torch should be kept continuously playing upon the surface to be welded to maintain it at the required heat. The flux will adhere to the rod and the flux coated rod should be again placed in the heated zone until it is at the point of fusion. It must not be held too close to the luminous cone of flame or the bronze will be burned. When a drop of the metal has been melted on the surface of the hot area to be welded, it will immediately spread and run out over the metal in a thin film, if the metal is the right temperature.

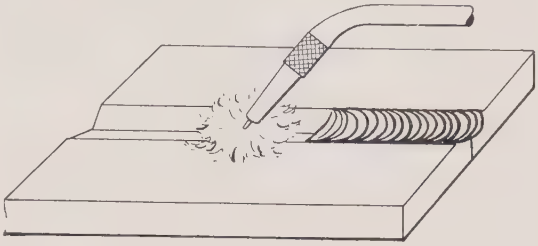


Figure 4—Sketch Showing the Method of Heating the Cast Iron to a Cherry Red Heat Immediately in Advance of the Bronze Weld. In this Instance the Luminous Cone of Flame is Held Close to the Casting to Utilize all of the Heat, but is Immediately Withdrawn When in Contact with Either the Bronze Weld Already Made, or the Bronze Rod.

The word "tin," applied to bronze welding, is somewhat confusing, but it means simply the coating of the surface of the hot cast iron with a film of bronze which will flow over it and adhere to it tenaciously. The secrets in thus "tinning" the surface of the iron lie in thoroughly cleaning the surface before heat is applied, using a good flux and maintaining the temperature of the surface of the cast iron close to the temperature at which the bronze will melt. If the metal is too cold, the bronze will not spread out and coat the area, but will lie in balls of metal too cold and chilled to flow.

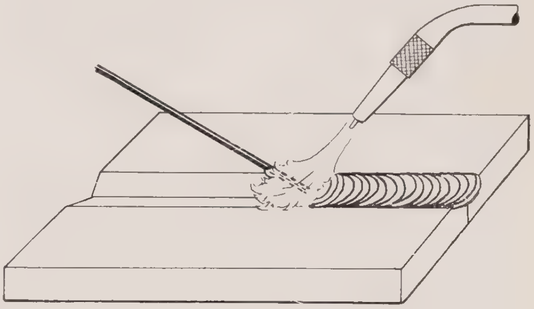


Figure 5—When the Area of the Casting Immediately Forward of the Weld has been Heated to a Cherry Red, the Torch is Partly Withdrawn and the Envelope of the Flame Utilized to Melt the Bronze Rod over the Surface to Thoroughly Coat or Tin It. This Section of the Weld is Then Built Up to Its Full Thickness. After the Tinning Operation, the Motion of the Rod May be the Same as in Fusion Welding if Desired.

Bronze is melted onto the heated surfaces thus described without allowing the luminous cone of the flame to touch the bronze. By moving the flame nearer the work and moving it away with quick intermittent movements, the envelope of the flame can be kept constantly on the work, but the luminous cone of flame held at a greater distance to control the temperature. Too much heat is indicated by excessive white clouds of zinc oxide, caused by the burning in the air of the vapor given off by overheated zinc. Zinc which will boil at a comparatively low temperature is a constituent of Tobin Bronze.

When the surfaces are clean and the heat is correct, the weld area can be coated with bronze rapidly and evenly. When this first coating or tinning application is completed, the joint may be built up to the desired thickness, applying flux as required.

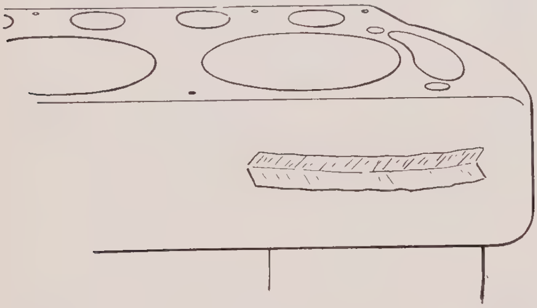


Figure 6—Sketch Showing the Method of Preparation of a Crack in the Water Jacket of a Cast Iron Cylinder Block. The Crack should be Chipped Out to a Vee, as Heretofore Described in the Text.

If a long break or crack in cast iron is to be welded a few inches at each end should be welded first, then a few inches in the center and the space between these welds filled up until the joint is completed. If a crack should extend from the edge of a casting part way across the surface, welding should begin at the inner end of the crack and proceed outward toward the edge. It is always good practice when a crack extends only part way across a casting, to drill a hole at the end of the crack to prevent the first heat when the torch is applied from extending the crack a greater distance.

Figure 3 illustrates a piece of cast iron chipped to a vee with the torch held in a position similar to that in fusion welding. This is not the way to hold the torch when bronze welding, because the bronze will be burned and the weld overheated. Figure 4 indicates the position in which the torch is held to heat the cast iron ahead of the weld to a cherry red, and in this manner utilize the full heat of the torch. When welding commences the luminous cone of the flame, however, must not be brought as close to the bronze as is indicated in this figure, but should be held, as shown in Figure 5.

Figures 4 and 5 show the pieces being welded in horizontal positions. If it is possible, it is good practice to incline the pieces so that the bronze weld is made up hill. This prevents the likelihood of flowing the molten bronze over surfaces which have not previously been tinned.

Strength of Bronze Welds

Bronze welds correctly made in this manner are from two to three times stronger than cast iron welds and closely approximate the strength of welds made in mild steel. They can be completed in about one-half to one-third the time required for welding with cast iron rods.

A very instructive test was made on one of the southern railroads to determine the strength of welded pieces of bloom iron four and one-quarter inches by four and one-quarter inches by twelve inches long. Two of these pieces were bronze welded with Tobin bronze; two pieces were oxy-acetylene welded with low carbon iron welding rods; two pieces were oxy-acetylene welded with patented steel welding rods and two pieces welded by the electric process. The railroad company desired to determine which process was most suitable for the welding of locomotive frames and made these tests to determine the relative strength of various types of welds. These tests were described in a paper, presented before the New York section of the American Welding Society in May, 1925. A summary of them follows:

Test No. 1

Two pieces of Tennessee bloom iron, four and one-quarter inches by four and one-quarter inches by twelve inches long, were welded together by the oxy-acetylene process, using one-quarter inch Tobin Bronze welding rods. This test piece was then placed in a wheel press in position to allow the press ram to bear directly against the center of the weld. Pressure was applied and the test piece started bending at seventy-five tons pressure. It bent two inches out of line at one hundred tons pressure. The pressure was released at one hundred tons, the specimen reversed and pressure was reapplied. The test piece started bending at one hundred tons and bent one and three-quarter inches out of line and cracked one-half way through the center of the weld at one hundred and twenty-five tons pressure.

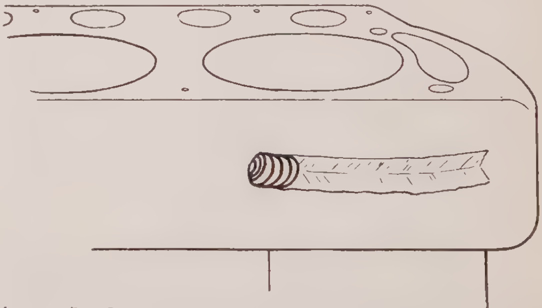


Figure 7—One End of the Crack should be Bronze Welded for only a Short Distance and then the Torch Applied to the Opposite End as Shown in Figure 8.

Test No. 2

Two similar pieces of the same grade of iron and of the same dimensions were welded by the oxy-acetylene process, using one-quarter inch low carbon iron welding róds. The test was made in the same manner. The test piece started bending at approximately seventy tons pressure and bent two inches out of line at one hundred tons. The pressure was released at one hundred tons, the piece was reversed and pressure again applied. The piece started bending at ninety-five tons, bent one and one-half inches out of line and cracked one-half way through the center of the weld at one hundred and ten tons pressure.

Test No. 3

Two pieces of the same grade of iron and of the same dimensions were welded by the oxy-acetylene process, using one-quarter inch patented steel welding rods. The test was made in the same manner. The test piece started bending at approximately eighty tons pressure, bent one and one-half inches out of line and broke clear through the center of the weld at one hundred tons pressure.

Test No. 4

Two pieces of the same grade of iron and of the same dimensions were welded by the electric process, using three-sixteenths inch welding rods. The test was made in the same manner. The test piece started bending at eighty-five tons pressure, bent one and one-quarter inches out of line, and broke in two pieces at one hundred tons pressure.

From these tests it will be noted that the bronze weld withstood fifteen tons more pressure than any of the other welds. It should also be noted that the most ductile of the welds were the bronze weld made in test No. 1 and the oxy-acetylene weld, with low carbon welding rods, made in No. 2. The welds made in test No. 3 and test No. 4 were both more brittle than those of No. 1 and 2. The bronze weld contracted only three sixty-fourths of an inch as it cooled.

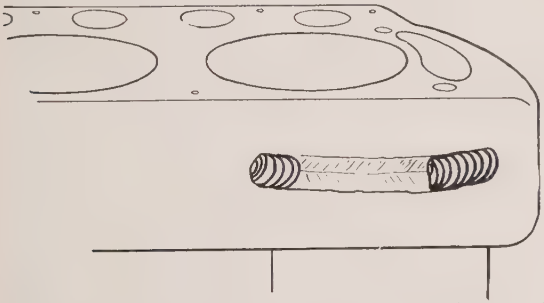


Figure 8—Welding First at One End and then at the Other should be Continued Until the Weld is Completed.

Bronze welding, therefore, eliminates some of the frame problems which are encountered because of the difficulty in expanding the frame sufficiently to prevent contraction strains when the weld is made with the oxy-acetylene fusion process.

Bronze Welding a Cast Iron Cylinder Block

Figures 6, 7, 8 and 9 illustrate the method of making a bronze weld in a cast iron cylinder block. The example taken is a small crack in the water jacket of the casting. This crack, of course, might have occurred in a different manner, or a piece might have been broken out of the casting, but regardless of the shape of the break, the method in general would be the same.

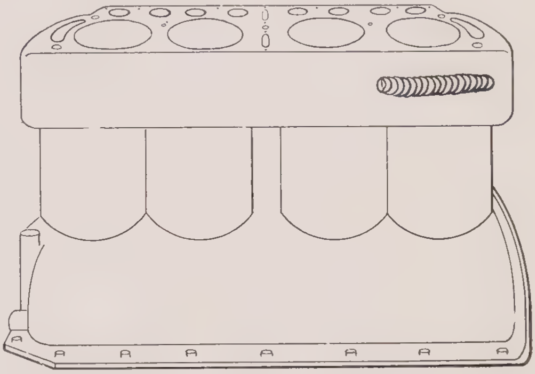


Figure 9—Sketch Showing the Completed Weld in the Cylinder Block. Other Welds in Other Locations can be Made by following the same Principles.

A hand chisel should be used to vee out the crack, as heretofore described. The casting, thus prepared for welding, is shown in Figure 6. The amount of dismantling which is necessary, of course, depends upon the location of the crack and the other work which it may be necessary to do upon the engine to put it in working condition. It often happens that when a break of this kind is to be repaired, other repairs necessitate the removal of the cylinder block from the car and dissembly of most of the parts. In this instance, it is easy enough to make the bronze weld, but in cases where some of the parts are still left attached to the block it is, of course, necessary to protect these parts with asbestos paper or wet asbestos to prevent them from being injured. The welder must use his judgment in this connection and often his ingenuity. In some instances it is necessary to weld a small crack of this nature with all of the parts of the engine assembled and the block mounted as usual upon its supports. In such instances great care must be taken to prevent injury to surrounding parts.

It should be remembered that the object in making a bronze weld is to prevent heating the casting any more than is necessary. For this reason only a small section of the break should be welded at one time and the heat as far as possible prevented from accumulating to too great an extent at any one portion of the casting.

A small portion of the veed crack should be bronze welded first as shown at Figure 7. The surface should be tinned for a short distance and then the section of the weld built up to its full depth over this area. The torch should next be applied to the opposite end of the break and tinned and welded as shown in Figure 8. In the meantime the end first welded will cool.

If the casting becomes overheated the torch should be removed for a short period of time and the heat thus controlled. A small section should next be welded adjacent to the first end of the crack and then a section adjacent the opposite end and this sequence continued until the entire weld has been completed as shown in Figure 9. The process will be found very simple if the foregoing principles have been thoroughly mastered and are carefully applied.

Welding Cast Iron Pipe

Cast iron pipe does not rust as quickly as steel pipe and for this reason it is more economical, particularly where the soil conditions hasten corrosion. In some districts the soils are so bad that the life of steel pipe is quite limited, whereas cast iron pipe will, under the same conditions, last much longer.

In 1921 the Southern Counties Gas Co. near Venice, Calif., found it necessary to lay pipe lines in soil where brackish or salt water lay close to the surface for a considerable portion of the year. This rendered the life of steel pipe very short and experiments were begun which led to the development of the bronze collar type of joint for cast iron pipe illustrated in Figure 10. Two lengths of plain end pipe were butted together and a bronze collar built up around the joint. This collar type of joint was developed after various methods of bronze welding had been experimented with. These included the vee type of joint, made by bevelling the ends of the pipe to an angle of forty-five degrees thus making a ninety degree angle between the surfaces to be welded. These bevels were made by machining the ends of the pipe and no thought was given to the exposure of the flakes of graphite and their effect upon the adhesion of the bronze, heretofore explained in this lesson.

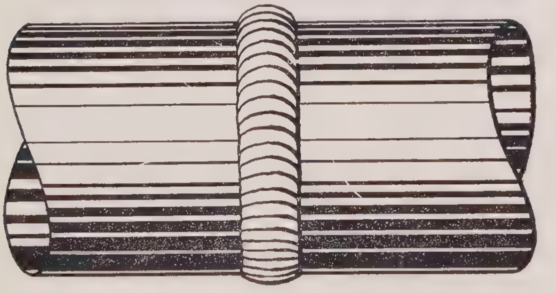


Figure 10—Sketch Showing a Collar Type of Bronze Welded Joint. This was the Type Originally Adopted, but Which Later Failed in Service By Breaking Through the Cast Iron Adjacent the Edges of the Built Up Collar

The result of these tests of the vee type weld showed less adherence of the bronze to the cast iron than with the collar type illustrated in Figure 10. For this reason, the vee type was abandoned and the collar type adopted for the work which was then to be carried out. As time went by, several other large jobs were completed using the collar type of bronze joint, but in almost every instance the following winter developed very serious breaks in the lines which necessitated elaborate repairs and cost a good deal of money. These conditions led to the abandonment of the bronze welding process by many of the gas companies as a process which held forth much promise, but did not withstand the severe contraction strains imposed by a cold winter.

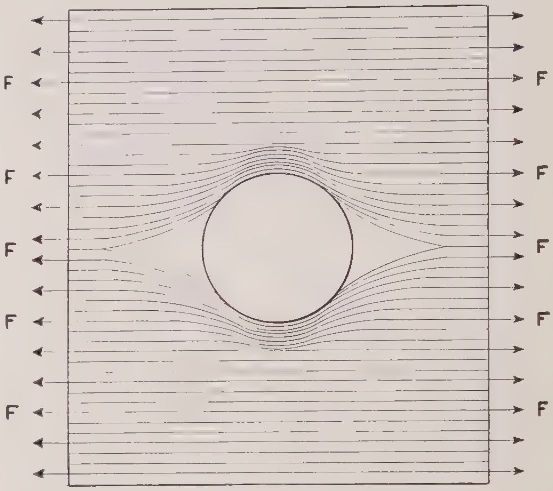


Figure 11—Sketch of a Plate with a Hole in It, Showing the Concentration of Stress Lines at the Edges of the Hole. The Stress Lines, F, are Indicated by the Arrows and Must Pass Around the Hole.

Engineers believed that the difficulty lay in a weakening of the cast iron immediately adjacent to the bronze weld, because in almost all cases the breaks occurred close to the edge of the bronze collar. Some of the cast iron pipe manufacturers realized the advantages of bronze welding cast iron pipe and set about to make a careful investigation of bronze welded joints to determine the real facts of the situation. One company in particular, the United States Cast Iron Pipe and Foundry Co., carried on a series of extensive experiments which brought forth a new type of joint, fully described by Mr. T. W. Greene in a paper read before the convention of the International Acetylene Association, held at Chicago, November 18, 1927. This type of joint is called the shear-vee type and is illustrated in Figure 14. Before describing this joint, however, it is well to consider the reasons for the failure of the collar type and to show that the heating of the cast iron adjacent to the edges of the bronze collar had nothing to do with the fact that the pipe broke at this point.

Stresses in a plate or bar may be indicated by parallel lines, as shown at F, Figure 11. This sketch shows a hole in a plate and indicates the fact that these stress lines must pass around the hole rather than straight through it, as they would if the plate were solid. If there were no hole in the plate, the stress lines would be parallel across the entire area of the plate as they are at the top and the bottom. With a hole, such as is shown, however, the stress lines must concentrate, or become bunched, on either side of the hole as indicated. This means that the stress at these points must be greater to resist the tendency of the external forces to pull the metal apart. If the external force is greater than the stress at these concentrated areas, the metal, if cast iron, will break. If the hole were not present the stress lines would not be concentrated, as indicated in Figure 11, and the external pull would be evenly distributed over the entire area and, therefore, unlikely to break the iron.

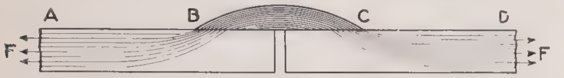


Figure 12—Sectional View of a Collar Type Bronze Welded Joint Showing the Stress Lines, F, Passing Upwards Through the Bronze Collar, B-C. The Concentration of these Lines at the Points B and C Is Clearly Indicated.

A section of the collar type of joint is shown in Figure 12. The forces, F, tending to pull the pipe joint apart caused by contraction of the pipe line along the length of the line must curve upward through the collar, B-C, in this type of joint. The two sections of pipe A and D are butted together as shown and the stress lines, F, cannot extend in parallel lines clear across this joint as shown at A and D. For this reason they become concentrated at B and C and the result is a point of weakness immediately adjacent to the bronze collar.

This indicates that the weakness of the collar type of joint did not lie in the process of bronze welding, but in the design of the joint itself. The bronze weld held with great tenacity and the bronze collar did not break, but the cast iron pipe broke at either the points B or C, where the greatest stress concentration took place.

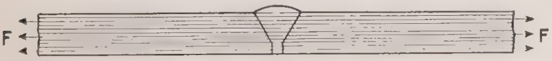


Figure 13—Sketch Illustrating a Vee Type Joint, Showing the Stress Lines, F, Passing Uniformly Through the Joint and Indicating No Concentration Whatever.

The investigation heretofore mentioned brought forth this condition and recommended a design of joint where the stress lines could pass directly through the joint, as shown in Figure 13. This is an illustration of a simple vee type of joint and it shows the stress lines passing directly and uniformly through the joint itself. This vee type of joint, properly applied, had a greater strength than the collar type, but still not quite enough to give the full strength of the pipe itself. It was necessary, however, in making the vee type of joint, to anneal the machined surfaces to remove the free graphite from these surfaces and thus enable thorough tinning of the surface and adhesion of the bronze to the cast iron.

In order to develop the full strength of the pipe, the upper portion of the bronze weld was extended somewhat and the shear-vee type of joint was the result, which is shown in Figure 14. This is the type of joint finally recommended as developing a strength equal to the pipe itself. Even with the shear-vee joint, expansion joints are necessary about every one hundred feet to compensate for expansion and contraction.

Bronze Welding Cast Iron Wheels

Broken or cracked gear and pulley wheels, both large and small, are frequently encountered by the welder and some of these breaks present quite difficult problems, if they are to be welded by fusion welding with cast iron welding rods. Preheating of the wheels extensively is necessary under these conditions. In some instances the entire wheel must be preheated and in others, parts of the wheel, including portions of the rim, spokes or hub, as the case might require.

In bronze welding, however, the expansion is less because less heat is required, and many of these difficulties are eliminated. Repairs can be made upon many broken wheels without any preheating whatever, except that accomplished with the torch. Heating with the torch is, however, essential in welding gear or pulley wheels, even in bronze welding, but the heating need not be as extensive and it can be confined to more limited areas.

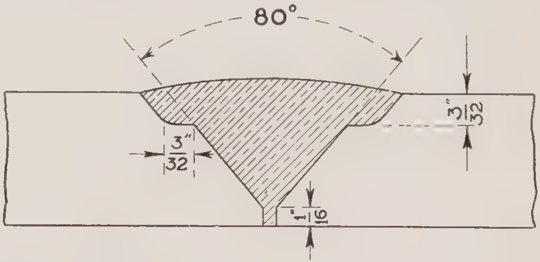


Figure 14—This is the Shear-Vee Type of Joint Recommended for Bronze Welding Cast Iron Pipe. Properly Made It Will Give the Full Strength of the Pipe Itself. Cast Iron Pipe May be Obtained from the Manufacturers, Bevelled as Shown, and Annealed for Bronze Welding.

Figure 15 illustrates a gear wheel which has a break through the hub, as shown at A. The break consists of a crack through the cast iron.

It is, of course, necessary to vee or chip away the metal adjacent to the crack from one side of the hub, if the metal is light, and from both sides if the section is heavy.

The heat of a fusion weld is very much greater both in temperature and in area than for a bronze weld. The wheel, if the break were to be welded by the fusion process with cast iron rods, would be expanded to a considerably greater extent than when bronze welded. In the instance shown in Figure 15, it is necessary only to heat the area adjacent the break A to a bright red heat in order to apply the bronze.

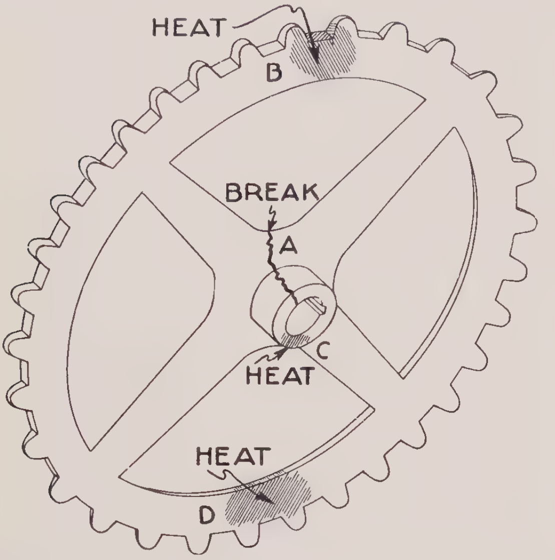


Figure 15—Sketch Showing a Cast Iron Gear Wheel with a Break Through the Hub at A. Heat Should be Applied at the Points A, B, C and D, Clear Across the Wheel in Line with the Break to Equally Expand the Wheel in Two Halves. This Opens the Break and At the Same Time Does Not Strain any Part of the Wheel.

If the student will consider the result of heating the point, A, to a bright red, he will readily understand why heating at the points, B, C and D is necessary. If A is expanded by heat, the rim, D, the hub, C, and the rim, B, must of necessity become strained and some part may crack. If the weld A, is made without heating these parts the strain may remain permanently in the iron and eventually cause a break at the weakest point in the section. If, on the other hand, heat is applied in equal amounts to the points, A, B, C and D, it is evident that one-half of the wheel will expand away from the other half equally and if it is allowed to cool down evenly, there will be no strain at all.

The principle is very simple and is applied whether or not the work is to be done by fusion welding or by bronze welding. If a wheel of this kind were large and the section of the metal heavy, it would be necessary to heat the four points, A, B, C and D, by building separate fires of charcoal, after enclosing each one of these sections in rough brick furnaces, and in this manner expanding the halves of the wheel on a line with a diameter drawn through the break. The work could also be done by using a fuel oil or kerosene preheater, or preferably two preheaters, and heating the points, A, B, C and D, alternately, keeping the heat as even as possible.

In smaller gear wheels, and when bronze welding is applied instead of fusion welding, this heating can be done with the torch. It is necessary, however, to apply the torch alternately to these various points and in bronze welding it should be accomplished as follows:

After the break, A, has been chipped and cleaned ready for bronze welding, the torch should be applied first at A, then at B, C and D, respectively, and this process should be repeated until all of the points, A, B, C and D, are heated and expanded equally, as the point, A, is heated to a cherry red. The surface of the iron is then coated with bronze, using flux as heretofore described, until the surface is thoroughly covered. This work should be done with the luminous cone of flame held away from the bronze rod and coating. Every few moments, however, the torch should be applied to the points B, C and D respectively, to maintain the heat at these points and keep the expansion even. When the surface has been fully covered, the section may be built up with bronze until the weld is completed, but during this entire operation, the points B, C and D must not be forgotten. Otherwise they will cool more rapidly than the point A, and the unequal expansion will cause strains in the iron which may eventually result in a break.

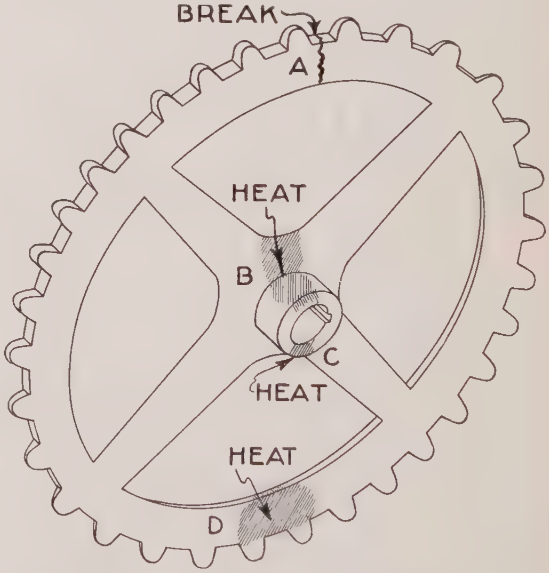


Figure 16—This Sketch Shows a Gear Wheel with a Break in the Rim at the Point A. The Manner of Heating is the Same as That Described for Figure 15.

In Figure 16 another example of a broken wheel is shown where the break occurred in the rim at A. If heat is applied only at A, in order to bronze weld the break, expansion will take place at this point and the hub will be strained at B. For this reason the same principle is used, as described for Figure 15, that of heating all of the parts of the wheel clear across the casting and thus expanding each half of the wheel equally. In welding a break similar to Figure 16, therefore, the break should be prepared by chipping it out to either a single or a double vee, depending upon the thickness of the section at the rim A, and if the wheel is a very big one, heating with either charcoal, or fuel oil or kerosene burners, at the points A, B, C and D.

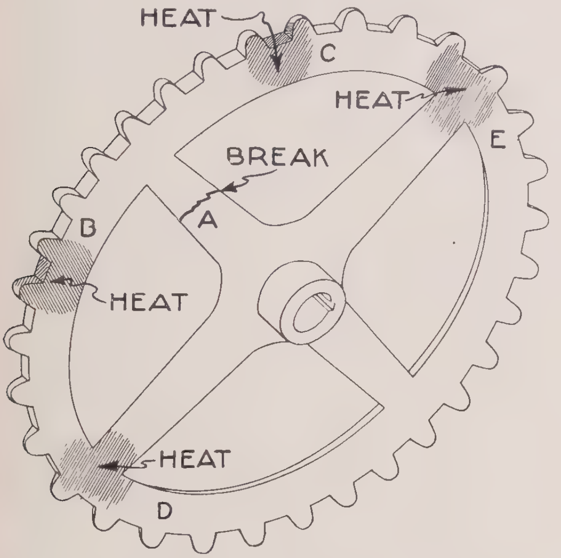


Figure 17—In this Instance a Break is Shown in One of the Spokes and Two Methods of Preheating are Indicated. If the Wheel is Small, Heat may be Applied at A, B and C. If the Wheel is large and the Rim and Spokes are Heavy, Heat should be Applied at D and E, to More Fully Expand the Rim and a Portion of the Spokes on Each Side of the Break.

If the wheel is a small one and the sections comparatively light, heating can be done with the torch, as described for Figure 15, care being taken that the heat is applied alternately to A, B, C and D, and then back again to heat each of these sections so that they will expand as evenly as possible. The bronze weld is accomplished at A and the torch intermittently applied to the various points B, C, and D to maintain the heat at these points while the weld is being made. The weld is made as heretofore described.

In Figure 17 a break is shown in one spoke as at A. There are two ways in which heat may be applied to expand the wheel and this would depend somewhat upon the number of spokes, the diameter of the wheel and the thickness of the section. If the wheel were a small one and the break to be bronze welded, the torch should be used for heating at the points B, C and A. This would expand the rim for an ordinary bronze weld without too much distortion. If, however, the rim were heavy and there were more spokes in the wheel than shown in Figure 17, the junctions of the spokes and the rim, as shown at D and E, of the first spoke on each side of the broken spoke should be heated. In this event it would be, of course, unnecessary to heat at the points B and C in addition to the heat applied at D and E.

In partial preheating of castings, it should be remembered that the object is to preheat and to cool the various parts equally. Some of the parts are thin, while others are thick, and the thicker sections of metal will cool more slowly than the thin sections. It is, therefore, necessary to maintain the thinner sections hot for a longer period of time than the thicker sections, so that they will cool down evenly. It will be appreciated that the skill of the welder in handling either preheating fires, or his torch, in heating and permitting the parts to cool, in this manner, is really the secret of the successful welding of castings. In some instances with complicated castings, it is better practice to preheat the entire casting, but this is not usually necessary when bronze welding.

Job Sheet No. 11

Bronze Welding of Cast Iron

For the work required in this job sheet the usual oxygen and acetylene cylinders, regulators, hose and torch, together with a tip of the size of a No. 5 are required. In addition to this some pieces of cast iron, a can of flux, similar to A-Mal-Gam No. 2, and some one-quarter inch Tobin Bronze are needed.

The work consists of building up a knob of bronze upon the surface of a piece of cast iron, so that when the knob of bronze is knocked off the cast iron with a hammer a thorough adhesion is shown by the tearing away of particles of cast iron.

1. Lay a piece of cast iron in a horizontal position on the welding table. Open the can of flux, place it on one corner of the table and procure a piece of Tobin Bronze welding rod.
2. See that the welding equipment is properly connected; then light and adjust the torch.
3. Bring the luminous cone to within approximately one-eighth inch of the surface of the cast iron and heat a portion of the cast iron about the size of a half dollar to a cherry red heat.
4. Hold the end of the Tobin Bronze welding rod in the envelope of the welding flame until it is hot, then dip the end of the rod into the can of flux where the heat of the rod will cause a quantity of the flux to adhere to it. Hold the end of the rod with the flux on it underneath the flame, well

away from the luminous cone, and rub it against the piece of cast iron. The flux will melt from the rod and spread out covering the surface of the cast iron. Repeat this several times until there is a coating of flux covering the spot to which bronze is to be applied.

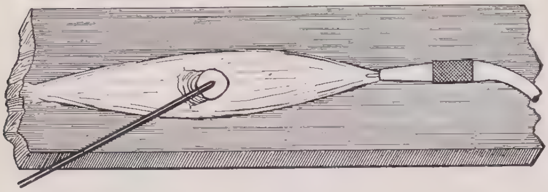


Figure 18—This Sketch Illustrates the Relative Positions of the Knob, the Torch and the Rod. Note that the Flame is Directed at the Bronze Knob in a Horizontal Position. The Luminous Cone is Kept Well Away from the Bronze Knob in Order that the Lower Temperature of the Flame Envelope may be Utilized.

5. When the flux has covered the surface of the cast iron, bring the end of the welding rod into the flame envelope and allow a small drop of the Tobin Bronze to melt from the rod upon the cast iron. If the cast iron is hot enough to receive the Tobin Bronze, this ball of metal will, as stated in the text, spread out and tin the surface of the cast iron. If, however, the cast iron is not yet hot enough, the bronze will remain in the form of a ball and will not adhere to the cast iron.

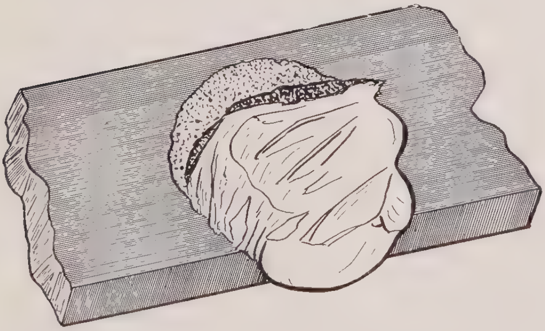


Figure 19—An Illustration Showing the Manner in Which a Well-Applied Bronze Knob will Tear the Cast Iron with It when Knocked Off with a Hammer. The Shaded Portion Represents a Piece of Cast Iron, the White Portion the Bronze and the Dotted Section Shows the Hole Left in the Cast Iron and the Cast Iron Adhering to the Bronze Knob.

6. When the cast iron is hot enough to receive the bronze, move the flame away from the cast iron to the position shown in Figure 5 of this lesson. Then, occasionally dipping the end of the rod into the can of flux, apply the Tobin Bronze and gradually build up a knob about three-quarters of an inch in diameter on the cast iron. This knob should be built up to a height of about three-quarters to one inch. While building up this knob it will be found necessary to hold the torch in a horizontal position as shown in Fig. 18 and to occasionally remove the flame from the weld momentarily to give the bronze a chance to cool and solidify.
7. After the knob has been built up to a height of approximately one inch with a diameter of three-quarters of an inch at the base, allow the piece to cool naturally. When cooled, place the cast iron in a vise, or hold it in some other manner, and proceed to strike the knob with a hammer until the bronze knob is knocked away from the cast iron. If the application has been correctly made, the piece of bronze will not break but the cast iron underneath it will break leaving a quantity of cast iron adhering to the bronze. The cast iron will be torn out of the original piece by the bronze. If, however, the cast iron was not hot enough or not properly fluxed and the bronze merely laid on top of the cast iron piece, the knob will break away cleanly and the surface of the cast iron piece will not be marred.

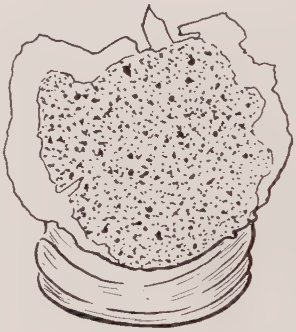


Figure 20—A Sketch Showing the Under Side of the Bronze Knob Which has been Torn Away from the Cast Iron. The Central Dotted Section Shows how the Cast Iron Has Adhered to the Bronze, while the White Outer Rim Represents a Portion of the Knob to Which the Bronze did not Adhere Because of Improper Use of Flux, or too Little Heat.

The building up of these knobs should be practiced until the student can apply the bronze in such manner that when the knob is knocked off it will tear the cast iron with it.

Questions:

1. What difference is there between welding steel and welding cast iron?
2. What effect has the rate of cooling upon cast iron?
3. What is "preheating"?
4. Why is it done?
5. Why is bronze welding cast iron becoming the principal method?
6. How should a surface to be bronze welded be prepared?
7. When bronze welding a long crack, should the weld be started at one end and continued to the other end of the crack? Why?
8. What is the strongest type of joint to use when bronze welding cast iron pipe?
9. Why is it necessary to heat other parts of a cast iron gear wheel or pulley when making a bronze weld?
10. What are the principal fuels used for preheating?

Lesson No. 12

Bronze Welding Cast Iron, Malleable Iron and Steel

CAST iron, malleable iron and steel can all be welded with bronze. The welder should know how to distinguish between castings made of these various metals, so that he will know what the metals are and how to weld them. In all three cases, Tobin Bronze is the most satisfactory bronze welding rod for this purpose, but a different flux is used for welding malleable iron and steel than for welding cast iron. It is, therefore, important that the welder should know the nature of the metal which he is about to weld.

A few remarks pertaining to the differences in castings made from these three metals will be advantageous. Castings made from cast iron have a smooth surface, but usually there is some sand to be found in this surface. The fracture of the casting shows fine, uniform dark grey crystals. If brought in contact with a grinding wheel, the sparks thrown off are similar to those shown in column 1, page 111, Lesson No. 7 for a short distance. They then break up to the form shown in column 4. When the iron castings are chipped with a chisel, the chips will break off. If the torch is applied to cast iron castings, no sparks are given off, except where impurities are included in the metal.

Steel castings, on the other hand, have a rough surface with some sand clinging to the surface and they weigh considerably more than cast iron. When a steel casting is broken, the cross-section shows large, bright, silvery crystals. The grinding wheel test shows a whiter spark than for cast iron, resembling No. 3, except that the iron streaks occur closer to the wheel. Chips from a steel casting cut with a chisel, will curl before breaking. When the torch is applied to steel castings a few bright sparks are given off.

Malleable iron castings are ordinarily smooth and free from sand and they weigh approximately the same as cast iron. Malleable iron is more fully described and its characteristics set forth in the following paragraphs.

Malleable Iron

Malleable iron castings are made for use upon the railroads and for parts of agricultural and other machinery. Some of the cheaper tools, like hammers and hatchets, and many pieces of builders' hardware are also made from malleable iron castings. Malleable cast iron has physical properties which lie between cast iron and steel. Its tensile strength ranges between 45,000 and 55,000 pounds, and it is made by an annealing, or heat treating process, from white iron.

In America, most of the malleable castings used are made of what is called black heart malleable iron. If one of these castings is broken, there is a bright, steely skin around the edge of the fracture, while the center of the casting is black and dull. There is another type of malleable casting used to a great extent in Europe called white heart malleable castings. These are produced by annealing, in the annealing oven, for a much longer period, until the carbon has been removed almost entirely throughout the casting. There is still another type of casting called the all black malleable casting from which pipe fittings are made. These are annealed in a material which will not decarbonize or remove the carbon from the surface, as will be described later.

In making malleable iron castings pig iron and steel scrap are melted in special furnaces and rapidly poured into molds. Molding machines are used to a large extent, because ordinarily a great many of the same parts are cast at a time. The castings are hard, white iron, because they have been cooled so rapidly that the carbon has not had the opportunity to precipitate as graphite to form grey iron. They contain about 2.3 per cent of carbon. The white iron castings are tumbled in tumbling barrels to remove all sand. They are then packed with mill scale, which is iron oxide, in cast iron or steel boxes, so that the iron oxide completely surrounds each casting and no two castings touch each other.

The annealing boxes are then placed in furnaces constantly maintained at temperatures of from 1,250 to 1,600 degrees Fahrenheit, and the castings are heat treated at this temperature for a period of about sixty hours. The result is the removal of the carbon from the surface of the castings, absorbed by the iron oxide, leaving a skin of soft iron. In the center of the casting the carbon has almost entirely changed to graphite, but the graphite does not occur in flakes as in grey iron castings, but in a finely divided condition like a powder. This carbon is called "temper carbon," or "temper graphite." When in this form the carbon has considerably less weakening effect than in the form of flakes.

White heart malleable castings, used in Europe, have been left in the annealing oven until the decarbonization of the surface has extended almost entirely through the casting. The all-black castings, referred to heretofore, are castings which have been packed and annealed in lime, fire-clay or some other substance, which does not absorb the carbon from the surface and they, therefore, lack the skin of soft iron which is characteristic of the black heart malleable castings which have been annealed in mill scale.

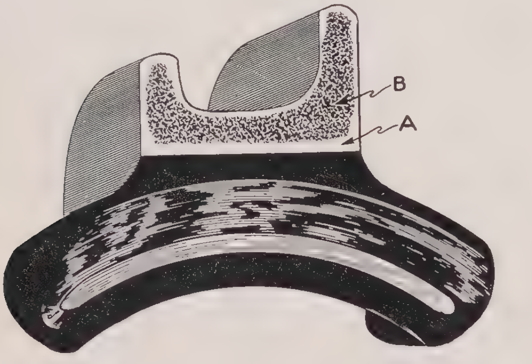


Figure 1—Sketch Showing a Fracture in a Malleable Iron Casting. The Soft Iron Skin, caused by Decarbonizing the Surface of the Casting Is Shown at A. The Black Heart of the Casting Is Shown at B.

In Figure 1 a fracture of a part of a hose coupling, used for the air hose upon railroad cars, is shown. This sketch indicates the soft, iron skin, A, which is bright in color and is not shaded. The black interior, B, of the casting is also clearly shown. Malleable castings, made in this manner, are much stronger than ordinary iron castings and will bend, rather than break, unless the load becomes too heavy. In this respect they have some of the advantages of steel, as far as strength and malleability are concerned and the advantages of cast iron, because they can be easily cast to any shape or pattern.

Bronze Welding Malleable Castings

If two pieces of malleable iron were veed out for welding, as usual, and welded with cast iron welding rods, the result would be two pieces of a tough, strong, malleable casting joined together by ordinary cast iron. The strength of the joint, therefore, would be reduced to the strength of the cast iron binding the two parts together, which would be less than one-half that of a malleable casting. For this reason, such a joint is but a makeshift and cast iron should not be used for this purpose.

If steel were used to weld two pieces of a broken malleable casting together, the result would still be a poor, weak weld, because when a puddle is melted in malleable iron, the soft iron surface and the steel welding rod, if used, fuses with the cast iron beneath it, with the result that there is a thin section of cast iron lying between the steel weld and the malleable cast iron. The strength of the joint is, therefore, again reduced to the strength of cast iron, which is too low for the purpose.

For the reasons just given, it is always better practice to bronze weld malleable iron castings. Tobin Bronze has a strength of approximately 54,000 pounds, as heretofore shown, while the strength of malleable cast iron ranges between 45,000 and 55,000 pounds per square inch. Bronze adheres tenaciously to the soft iron skin of the malleable castings and, if built up or reinforced around the castings, the joint will be strong enough for most purposes. Of course, the joint with the black heart of the casting will not have the strength of the union between the soft iron surfaces.

The malleable qualities of the castings are not injured in bronze welding, because the heat required does not exceed 1,375 or 1,400 degrees and the malleable casting is not raised to the point of fusion.

Malleable iron castings can be determined by the appearance of the fracture, as described above and, if the fracture is clean, the appearance is so distinctly different from cast iron that it can be easily distinguished. If a malleable casting is held against a grinding wheel, there will be, at first, a few mild steel sparks as shown in No. 2, page 111, Lesson 7, and these have a reddish tinge. As the interior of the casting is reached the sparks thrown change in appearance to approximately those shown in column 3. If malleable castings are chipped with a chisel the first chip will curl, as iron does, and then will break indicating the cast iron interior. When a spot on a malleable iron casting is heated with the torch, a small hole will appear just as the metal begins to melt. This hole is caused by the formation and escape of gas. The surface of the metal as it is melted is clear, clean metal and is not covered by a coat of oxide or scale, as is the case with cast iron. As the puddle becomes larger and hotter, larger quantities of gas are formed, by melting the interior iron, which bubble out through the surface and cause this portion of the surface of the metal to recede or depress slightly. These distinguishing features of malleable iron make it very easy to recognize.

When bronze welding malleable castings, the soft iron surface or skin is not affected, because the casting is only raised to a cherry red heat and the surface is not melted. Likewise, gas does not form in the metal, because the metal is not melted. If the weld is heavily reinforced around the surface in the shape of a collar, the strength of the repair will be considerably increased.

The preparation of the casting for bronze welding malleable castings is the same as heretofore described for bronze welding cast iron. The parts should be bevelled in a manner which will enable the operator to begin bronze welding at the bottom of the section. If the bronze weld is a short one, it should be tinned and the section built up as rapidly as possible. If the crack is a long one, however, it should be tinned and built up in sections as heretofore described. The casting should be heated to a cherry red and a good malleable iron flux used, similar to A-Mal-Gam No. 3. Good tinning is essential, but the technique of bronze welding malleable iron castings does not differ from that described for bronze welding cast iron. It will be noted that the soft steel surface or skin of the malleable casting tins better than the black interior of the casting.

Bronze Welding Rods

As stated in Lesson No. 11, there are a number of different bronze welding rods upon the market, some of which are particularly suitable for specific work. The welder should know just what these rods are intended for and what their principal characteristics are. On page 164, Lesson No. 11, there is a table showing the approximate melting points and the tensile strengths of various welding rods of the Anaconda brand. The first of these is Tobin Bronze. As stated in the text of the lesson, Tobin Bronze is the alloy recommended for almost all bronze welding. Its tensile strength is high, it is ductile, fuses readily and flows freely at low welding temperatures. It is also easy to machine or finish.

Manganese bronze melts at a lower temperature than Tobin Bronze, but has a higher tensile strength. It produces a stiff, strong bond, but it is not as ductile as Tobin Bronze. It should be used where resistance to wear is the principal demand and where the lack of ductility will not be disadvantageous. Phosphor bronze is similar in color to pure copper and can be used where a tougher and stronger bond is required than can be obtained by using silicon copper. Both Tobin and phosphor bronze are used for welding galvanized iron and the welding operation does not in this instance injure the galvanized coating. It is necessary, however, carefully to control the heat in welding galvanized steel, so that the flame will not burn the galvanized coating away. This is described later in these lessons.

Brazing metal is used for repairing brass castings and for brazing iron or steel, where the greatest strength is not required. A braze made with this metal may be satisfactory for many purposes, but it has not the strength of a bronze weld made with Tobin Bronze. Silicon and electrolytic copper are discussed later in the course in the lesson on welding copper.

Linear Expansion of Metals

As the student's experience with welding various metals increases, he should be familiar with the linear expansion of these metals and their relative behavior. The figures given in the following table are approximate, but serve to indicate the relationship, insofar as expansion is concerned, between the various metals. They are given in inches per 100 degrees rise in temperature and show, for instance, that zinc is at the top of the list expanding 0.169 of an inch per ten foot length, while cast iron occupies the lowest position on the list, expanding only 0.067 of an inch. Expansion and contraction are factors to which the welder must give very careful consideration, because he must know what to expect of a casting when he applies heat to it.

Linear Expansion of Metals Per Ten Foot Length, Per 100 Degrees, Fahrenheit, Rise in Temperature.

Metal	Inches
Zinc	0.169
Aluminum	0.148
Tin	0.139
Silver	0.129
Bronze	0.119
Brass	0.115
Copper	0.106
Nickel	0.083
Wrought Iron	0.078
Steel	0.076
Cast Iron	0.067

Welding Malleable Iron Parts of Farm Machinery

Because of its strength malleable iron is used to a considerable extent in making parts for farm machinery. These, of course, break upon occasion, if strained or loaded beyond their capacity, and represent a very profitable field for the job shops located in the country and in the smaller towns. Figure 2 illustrates a lever quadrant for a farm implement. This quadrant was made of malleable cast iron and was broken and bronze welded as shown in the lower right hand corner of the illustration. The quadrant was about eight inches in height and nine inches in width. The thickness of metal welded was one-half inch, at the outer edge, and one-quarter inch in the web. The length of the weld was approximately three inches. The two broken pieces were ground to an angle of about sixty degrees, lined up in position and tack welded with bronze.

It is usually good practice to grind, as nearly as possible, to an included angle of ninety degrees, but it is not always possible to do this without grinding off too much of certain parts. In this instance there were no complications with reference to expansion, because the arm at the lower right hand of the malleable casting was free to expand without interfering with any of the other parts. Bronze welding was, therefore, accomplished by heating the casting at the break to a cherry red heat, dipping the Tobin Bronze welding rod in the flux box and thoroughly coating the surfaces with flux. The torch was then held momentarily close to the rod and then withdrawn, in such manner that the Tobin Bronze was melted over the hot malleable iron casting and the surface thus thoroughly tinned. The position of the torch was such, however, that there was just enough heat to maintain the casting at a cherry red temperature and to fuse the bronze over the surface, but not enough heat to burn the bronze.

The weld was then built up half way, clear across the break, and then, on the backward movement of the torch, the weld was completed to the full thickness of the section. The casting was then turned over and the bronze weld reinforced across the under surface, despite the fact that the vee had been made entirely from one side.

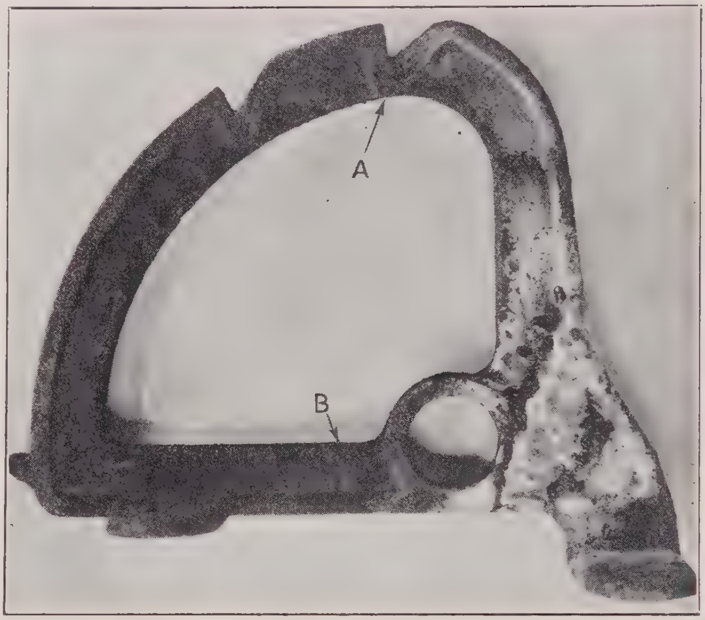


Figure 2—Photograph Showing a Quadrant for a Farm Implement Which Has Been Bronze Welded. In this Instance Expansion and Contraction Did Not Present any Problem, but If the Break Had Been at A, Instead of Where Shown, It Would Have Been Necessary to Heat at A and B Intermittently, To Expand the Arms of the Casting Equally.

As stated before, this casting did not present any particular problems with reference to expansion, because of the location of the break. If, however, the break had been at the point marked A, the condition would then have been entirely different. The preparation of the break, in this instance, would have been exactly the same and the routine of bronze welding would have been similar, but the expansion of the casting would require heating the arm at B simultaneously with that at A. As the bronze weld was built up at A, intermittent movements of the torch would be necessary to keep the arm, B, expanded equally with A, and as the casting cooled down it would be necessary to control the contraction in similar manner. The object would be equal expansion of the two arms and in like manner equal contraction.

Building Up Worn or Low Surfaces with Bronze

The possibilities of building up worn surfaces of iron and steel parts with Tobin, or manganese bronze seem almost endless. There are many parts of machinery made of cast iron, malleable iron and steel, which become worn and unserviceable in use. Building these worn surfaces up to their proper thickness or height, with Tobin Bronze, is an industrial economy of great proportions. Such possibilities range all the way from building up large, worn surfaces upon locomotive parts, like piston rods, worn slide valves, etc., and marine and stationary engine parts, to such small jobs, as the one shown in Figure 3.

In this sketch a furnace door is illustrated which fitted so badly to the furnace casting that it was constantly leaking air. The flange which came in contact with the furnace casting was too short along the edge A, B, C in the sketch. This edge was built up with Tobin Bronze, as indicated, and finished off to a correct surface with the result that the door was saved without spending the time, money or inconvenience of getting a new one.

A job of this kind does not present any particular difficulty, because only the edge of the casting is heated and the edge is free to expand. Therefore, it is only necessary to heat this edge with the torch to a cherry red, and, applying flux and Tobin Bronze, proceed in the manner heretofore described, making a ripple weld along the top of the flange of the casting. After welding in this manner it is very easy to face off the bronze and make a smooth, clean job.

Bronze Welding a Steel Patch to a Tractor Crank Case

In figure 4 there is an illustration of a cast iron crank case for a farm tractor. The hole indicated in the sketch had been broken out of the side of the case by a loose connecting rod. When the hole was broken the pieces of cast iron were lost and the welder found it necessary to substitute a piece of sheet steel for the broken and lost parts. The procedure in this case was to cut out a piece of a steel plate, of a thickness equal to the thickness of the wall of the crank case, to fit the hole approximately.

A patch made in this manner should be about one-sixteenth of an inch smaller all around the edges than the hole, so that a space one-sixteenth of an inch in width will be left for welding between the steel and the cast iron.

The patch is shown in Figure 4 shaded. In a job of this kind it is necessary, of course, to consider the effect upon the cast iron when heat is applied to the wall of the casting. It is true that in this case there would be some allowance for expansion and contraction because of the fact that the steel patch is not as stiff and rigid as the cast iron. In spite of this, however, it is essential to compensate as much as possible for the heat and to prevent it from becoming too great at any one point. For this reason, the patch is inserted and after being tack welded at the points A, B, C and D, Figure 4, the welding is done intermittently, at the point A for about an inch, then at the point C for about the same distance, then at the point B and finally at the point D. This is based upon the same principles as those heretofore indicated for the welding of pipe.

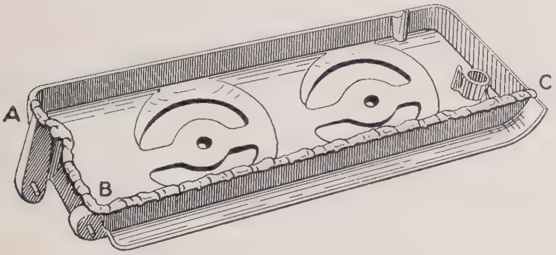


Figure 3—This Sketch Illustrates the Building Up with Bronze of the Edge of a Cast Iron Furnace Door. The Door Did Not Fit Closely to the Furnace Casting and Leaked Air. The Rough Bronze Weld Is Shown at A, B and C Along the Top Edge of the Casting.

If the weld were to start at A and continue all the way around the patch until it was completed at A, the strain placed upon the iron would be such that in all probability when the patch cooled down the thin cast iron wall would break. For this reason, it is particularly important that the heat be kept as low as possible and only the edge of the cast iron heated to a cherry red as the bronze is applied. It is often good practice to surround the patch with wet asbestos to confine the heat. The procedure is the same as heretofore described for the welding of cast iron. A flux should be used, similar to A-Mal-Gam No. 2. Of course, the edge of the hole in the casting and the steel patch should be thoroughly cleaned, before welding is attempted, and the flux and the bronze applied, as has already been described. The intermittent welding of the patch should be continued at opposite sides of the patch until the job is complete.

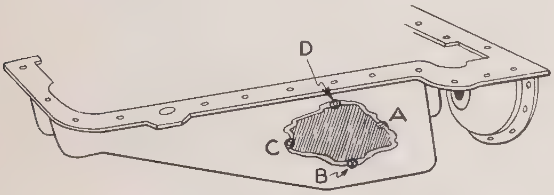


Figure 4—This Sketch Shows a Cast Iron Tractor Crank Case with a Hole Broken through the Side by a Loose Connecting Rod. The Pieces Were Gone and It Was Repaired by Inserting a Steel Plate, Illustrated by the Shaded Area, which Was Bronze Welded in Place.

Building Up Worn Valve Seats

The valve seats of cast iron cylinder blocks for automobiles and tractors sometimes become worn as is shown in Figure 5 where B represents the worn valve seat and A represents one of these seats built up with bronze. Manganese bronze may be used if desired, because it has a greater resistance to wear than Tobin bronze and in this case the weld is not subject to great strain. However, Tobin bronze will suffice for this work, if available, and produces a job which will last a long time. The procedure is no different from that heretofore described, but it is usually excellent practice to enclose the cylinder in a rough fire-brick furnace and heat it slowly and evenly to slightly more than a black heat. This can be done either with a city gas burner, using city gas only, or with a small quantity of charcoal.

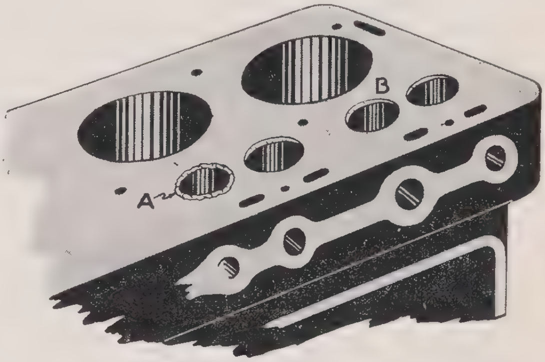


Figure 5—Sometimes the Valve Seats of Cast Iron Cylinder Blocks Become Badly Worn. In Such Instances Bronze Can Be Applied to Build up the Seats as Shown at A. They are afterward Ground and the Repair Makes a Very Serviceable Job.

It is not necessary to heat the casting as hot as it would be heated if a fusion weld were to be accomplished and, if it is heated evenly to cause equal expansion, there is little chance of difficulty when the casting cools down. Such heating is the safest method and should be used in most cases.

Welding a Broken Punch Press Frame

Sometimes a punch press is repeatedly overloaded with the result that finally strains occur in the cast iron walls forming its frame, which ultimately cause breaks. Such a break is shown in Figure 6. The punch press in this instance is veed out by chipping the cast iron away with air hammers at both sides as indicated. After chipping away both edges of the part to angles of from forty-five to sixty degrees, the punch press is laid on its front face and the two parts matched up. They are then very carefully lined up, supported underneath upon a brick platform and clamped with clamps and rods to hold the two parts securely in position. A rough fire-brick furnace is then built up around the break to include only the middle portion of the casting.

This is what is known as partial preheating of a casting. It is not necessary to heat the entire casting, because it will expand lengthwise with entire freedom and preheating is done more largely to save fuel and to heat the casting to a little more than a black heat. The casting in this position, in the fire-brick furnace is shown in Figure 7. Heat radiates rapidly in a casting of this size, and unless the torch is augmented by additional heat of some kind, it is almost impossible to maintain sufficient heat to make a proper weld. When a large casting is heated to the right temperature, bronze welding is easy and very rapid and the edges of the metal can be readily tinned in the usual manner and the bronze flows well.

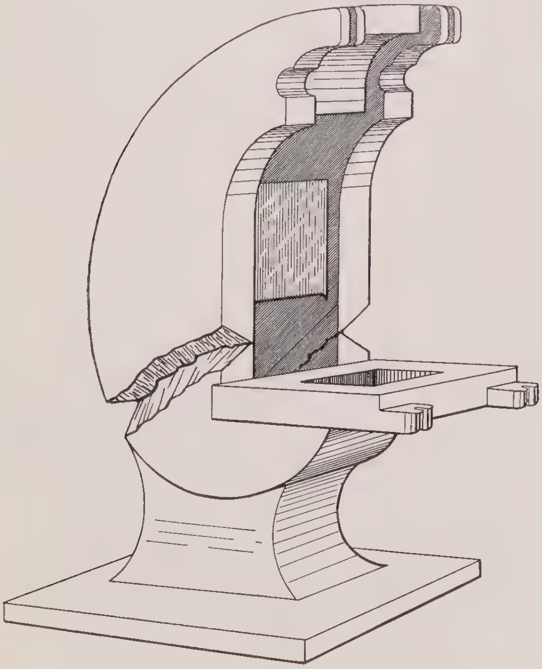


Figure 6—Sketch Showing a Broken Punch Press Frame with Two Breaks Clear Through the Casting on Each Side. The Lower Portion of the Frame Is Solid, but the Two Breaks Indicated Are in Cast Iron, Approximately Four Inches in Thickness. This Sketch Has Been Made to Illustrate an Actual Job of Which Photographs Could Not Be Obtained.

The vee, of course, is very deep and under normal conditions, if it had been possible to get at the inside of the walls of the press, the vee would have been a double vee, instead of a single vee. The welder, too, would have had much difficulty in reaching the interior walls, and it would not have been as satisfactory from a welding point of view as the single vee shown. A double vee requires only one-half the amount of bronze needed for a single vee and is, therefore, more economical. It also makes a stronger joint.

The position of the casting shown in Figure 7 is such that both welds must be made vertically. A part of one side wall of the brick furnace is pulled away, the weld made and the opening covered with asbestos paper. The other side is then done in the same manner. This method helps in preheating both sides evenly and avoids turning the casting over which would otherwise be necessary.

The method of procedure does not differ from that already described except that the section is larger and the amount of bronze involved is considerably greater. A relatively short section of the hot casting is coated with flux, brought from the flux box on the rod, and spread over the surface. The surface is then thoroughly tinned with bronze and this section built up as rapidly as possible until the full depth of the vee and proper re-enforcement has been completed. The next section should be tinned and this section built up to the full depth and width in similar manner. This procedure should be continued until the full length of the break has been welded.

Preheating a section of this kind should preferably be accomplished with charcoal, although fuel oil or kerosene preheaters may be used if desired. The casting is a large and heavy one and preheating for bronze welding should be done with just fire enough to produce the right temperature.

When the welds have both been completed the casting should be entirely covered with asbestos paper and allowed to cool slowly. Welding a casting of this kind with bronze requires much less heat than if fusion welding with cast iron rods were attempted; and the result, as heretofore stated, is a stronger job than an all cast iron weld.

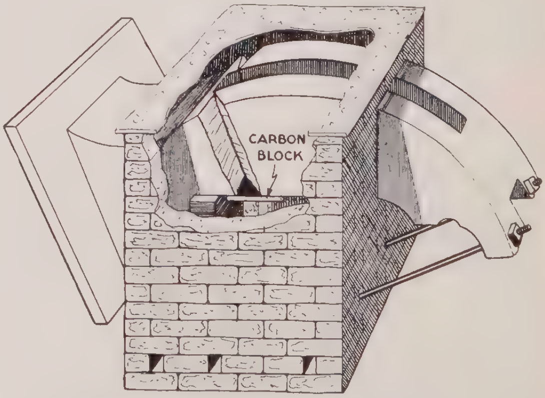


Figure 7—A View of the Punch Press Frame on Its Face with a Fire-brick Furnace Built Around the Center of the Casting. This Is an Illustration of Partial Preheating, Which Is Done, Not Because of Difficulty in Expansion and Contraction, but Because the Use of Cheaper Fuel for Heating Decreases the Cost of Welding and Enables the Welder to Accomplish His Work to Better Advantage.

Welding a Cast Iron Manifold for a Farm Tractor

In the illustration, Figure 8, a break is shown at A-B. This break should be veed out, as usual, to enable the weld to penetrate clear through the section, but before beginning to weld, the welder should consider the effect of heat upon a casting of this kind. It is obvious that if heat is applied to the crack, A-B, without any heat at the other side of the casting, the metal will expand and set up a strain in the metal at the side opposite the crack. Cast iron is very stiff and the result of such heat would in all probability be the continuance of the crack further around the casting.

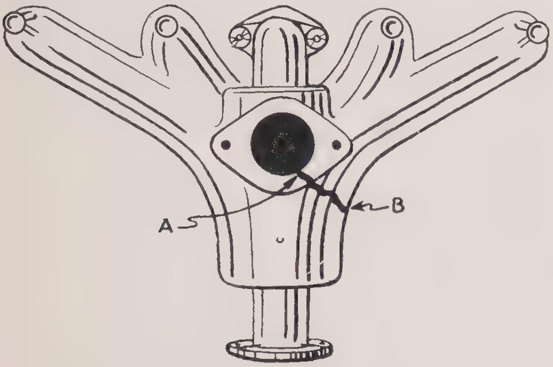


Figure 8—Sketch Showing a Manifold for a Farm Tractor. The Break Is Indicated at A-B.

It is also obvious that if the heat is applied clear around this portion of the casting, the entire end will be expanded end-wise toward the manifold inlet, and in this instance there will be no strain and the expansion will be equal clear around the circumference of the casting. Preheating, therefore, should be accomplished in this manner all the way around the casting. This section around the inlet of the manifold could, of course, be enclosed with several fire-brick and some asbestos paper and heated with a city gas and air, or a kerosene preheater.

Many welders consider, however, in a case like this that, if it is necessary to preheat the casting, as has been described in this instance, it is just as well to use cast iron welding rods, a cast iron flux and to make a fusion weld, as to make a bronze weld. This is largely a matter of preference and will depend upon the operator. Some welders are more skilled at making bronze welds while others become more skillful with fusion welds; hence in a case of this kind, where it really makes no difference which is used, it is a matter of choice.

Bronze Welding Breaks in a Locomotive Exhaust Pipe

A railroad accident caused serious breaks in the locomotive cylinder casting, shown in Figure 9. There were other breaks in the opposite cylinder casting, but this break will serve to show what can be done in bronze welding. In Figure 9 it will be noted that two breaks have occurred at A and B in the cast iron exhaust pipe which lies within the main cylinder casting. At the same time a large hole, D-C, was broken out of the forward part of the casting in front of the exhaust pipe. In order to make this repair a piece of cast iron, A, was fitted in place, securely fastened with three bolts as shown and bronze welded in position. The crack, B, was then bronze welded which completed the repair of the exhaust pipe. The piece, E, was assembled from broken parts bronze welded together, placed in the hole and bronze welded all around. The usual methods were used in this procedure.

This repair was fully described in the October, 1925, issue of the Acetylene Journal. All chipping was done with air chippers and Tobin Bronze was used throughout. It required about 2,000 cubic feet of oxygen, a like amount of acetylene and approximately 204 pounds of bronze welding rod to complete the entire job on both castings. This work is described and illustrated here to enable the student to appreciate the importance and size of repairs which can be readily accomplished by bronze welding. The saving, of course, in this case was very great, because otherwise it would have been necessary to remove entirely the right cylinder casting and replace it with a new one. The break in the left casting, which is not shown in the sketch, could have been patched by mechanical means, but the break illustrated could not have been patched by any other process than with the oxy-acetylene torch.

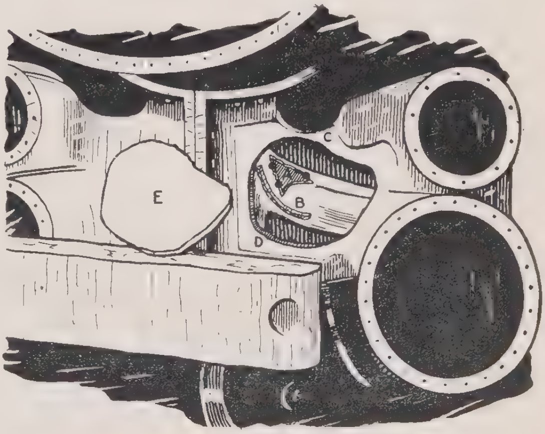


Figure 9—Sketch Showing a Locomotive Cylinder Casting Which Was Badly Broken and Subsequently Bronze Welded. This Sketch Shows the Extent to which Bronze Welding May Be Applied to Locomotive Cylinder Castings. The Work Was Done with Very Little Preheating and the Saving Was Very Great.

Bronze Welding an Automobile Cylinder Block

In the early fall and winter the job shop and the garage will have much experience in welding broken water jackets of automobile cylinders which have been frozen. In fact, such repairs, usually the result of a sudden cold snap, are profitable to the average shop. There are automobile owners, however, who want to drive up to the door of a shop and have a repair made in the cylinder block without dismantling any part of the car and some of them insist upon the work being done in this manner.

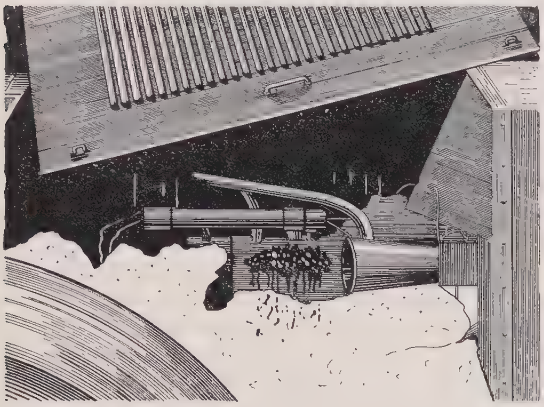


Figure 10—A Sketch Showing an Actual Job of Welding the Water Jacket of an Automobile Cylinder Without any Dismantling Whatever. The Job Was Done with the Electric Arc and Then Coated with an Iron Cement to Prevent Leakage. Such Practice by any Process Is Not Recommended.

In figure 10 a job of this kind is illustrated, just as the work was completed and this job was done in the following manner. The hood of the car was opened up, the water drained out of the cylinder, asbestos placed around the various parts to prevent sparks from igniting oil or grease, and the weld made with an electric arc. It will be appreciated that in this instance a hot steel electrode was melted upon a relatively cold cast iron wall with the result which would normally be expected under such circumstances. When the welding was completed the weld was coated with an iron cement to prevent leaking and the job was pronounced completed.

It is hardly reasonable to expect a repair made in this manner to be successful and the reason for illustrating this job in this manner is not to cast any reflections upon any process but to illustrate to the welder that the automobile owner who drives his car up to a job shop and expects a repair made, without any dismantling whatever, or any attempt to heat the cylinder block, is expecting more than can normally be accomplished.

It is unreasonable to suppose that a welding shop can accomplish a thoroughly good job, even by bronze welding a cylinder, unless the cylinder is dismantled to such an extent that some preheating may be accomplished. Some welders will run the engine until the water is boiling hot, then drain it away and immediately start to bronze weld, but the temperature which can be attained in the cylinder is not much more than 200 degrees, and while this is much better than a cold cylinder, at the same time the metal has not been fully expanded at this temperature with the result that if the weld is in a difficult place, where unequal expansion is likely to take place, a strain will be placed in the casting if great care is not taken to compensate for it.

Of course, the amount of dismantling required depends entirely upon the location of the break, but it is far better practice for a shop manager to state to the automobile owner in the beginning, that a certain amount of dismantling is necessary, in order to produce proper results, and to insist that the work be done in this way, rather than to attempt the work, absolutely cold, with the chances of making either a poor weld or further cracking or straining the casting. It is better practice for the job shop and will ultimately result in a better reputation if the shop refuses to do the job entirely, unless it is done in a satisfactory manner. Of course, the crack may occur in the head of the motor and in this instance the situation is quite different, because the head can be removed from the car without a great deal of dismantling and the weld accomplished as it should be.

Welding Locomotive Frames

Locomotive frames are made of cast steel, the sections varying in width and depth from three inches by three inches to six inches by six inches, or perhaps five inches by seven inches, depending upon the design of the frame and the location of the break. Locomotive frames can be welded by the oxy-acetylene fusion method, with the electric arc, by making a Thermit weld, or by bronze welding. Bronze welding is the newer process and has been adopted by several of the large railroad systems. The oxy-acetylene fusion method is still practiced by some railroads, but a large number of roads are electrically welding frames. A bronze weld in a locomotive frame can be accomplished in about one-half the time of fusion welding and at considerably less expense. The reason why electric welding has been used to such an extent for frame welding lies in the fact that when an electric weld is made the adjacent steel is not heated for as great a distance on each side of the weld, with the result that there is less expansion and consequently less contraction.

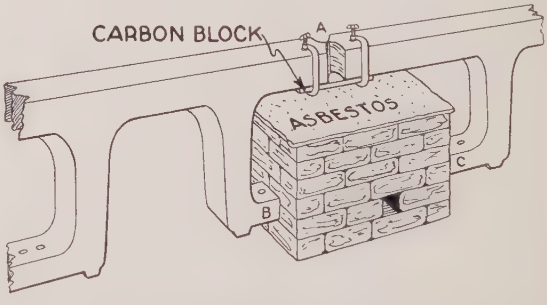


Figure 11—Sketch Showing a Locomotive Frame Prepared for Welding, with a Preheating Furnace Constructed to Preheat the Lower Chord of the Frame.

In other words, the electric weld more highly concentrates the heat to a smaller zone than is the case when fusion welding is accomplished with the oxy-acetylene torch. For this reason electric welding has been used to a very considerable extent and particularly in cases where it was almost impossible to obtain the necessary expansion, except by extensive preheating. Preheating, of course, slows down the job, because of the time required and increases its cost to a very considerable extent.

Volume and Weight of Weld Metal in 90-Degree and 60-Degree Vees

Thickness metal, ins.	Weld metal in 1-in. length of 90° vee, cu. ins.	Weight of steel weld metal in 1-in. length of 90° vee, pounds	Weight of cast iron weld metal in 1-in. length of 90° vee, pounds	Weight of Tobin Bronze weld metal in 1-in. length of 90° vee, pounds	Weld metal in 1-in. length of 60° vee, cu. ins.	Weight of steel weld metal in 1-in. length of 60° vee, pounds	Weight of cast iron weld metal in 1-in. length of 60° vee, pounds	Weight of Tobin Bronze weld metal in 1-in. length of 60° vee, pounds
¼	0.062	0.017	0.016	0.0188	0.035	0.009	0.009	0.0106
⅜	0.140	0.039	0.036	0.0425	0.080	0.022	0.020	0.0243
½	0.250	0.070	0.065	0.0759	0.144	0.040	0.037	0.0437
⅝	0.390	0.110	0.101	0.1183	0.225	0.063	0.058	0.0683
¾	0.562	0.159	0.146	0.1705	0.324	0.091	0.084	0.0983
⅞	0.765	0.216	0.199	0.2321	0.441	0.124	0.115	0.1338
1	1.000	0.283	0.261	0.3034	0.577	0.163	0.150	0.1751
1⅛	1.265	0.357	0.330	0.3838	0.729	0.206	0.190	0.2212
1¼	1.562	0.442	0.407	0.4739	0.901	0.254	0.235	0.2734
1⅜	1.890	0.534	0.493	0.5734	1.090	0.308	0.284	0.3307
1½	2.250	0.636	0.587	0.6826	1.298	0.367	0.338	0.3938
1⅝	2.640	0.747	0.689	0.8010	1.523	0.431	0.397	0.4621
1¾	3.062	0.866	0.799	0.9290	1.766	0.499	0.460	0.5358
1⅞	3.515	0.994	0.917	1.0665	2.028	0.573	0.529	0.6153
2	4.000	1.132	1.044	1.2136	2.308	0.653	0.602	0.7626
2¼	5.062	1.432	1.321	1.5358	2.920	0.826	0.762	0.8859
2½	6.250	1.768	1.631	1.8962	3.606	1.020	0.941	1.0941
2¾	7.562	2.140	1.973	2.2943	4.363	1.234	1.138	1.3237
3	9.000	2.347	2.349	2.7306	5.196	1.470	1.356	1.5765

Add 15 to 20 per cent to the above figures for reinforcement and loss.
The weight of steel is 0.283 pounds per cubic inch; of cast iron, 0.261 pounds per cubic inch and of Tobin Bronze, 0.3034 pounds per cubic inch.
The above table considers the metal veed from one side only; if veed on both sides the volume and the weight of the weld metal are one-half of the above figures.

The procedure for oxy-acetylene fusion welding of a frame is clearly indicated in Figure 11. The break is in the top bar of the frame at A. This break is veed out by cutting away the steel with the cutting torch to a circular vee, shown in Chart No. 4, page 15, Lesson No. 2. This shape of vee is a little more economical insofar as the amount of weld metal required is concerned than the ninety degree vee, and it makes a weld which is fully as strong.

A fire-brick furnace is constructed around the lower part of the frame B-C. A charcoal fire is built in this furnace, which is covered with an asbestos sheet or board cover, and the lower part of the frame is expanded. It should not be heated to a bright red heat, because if this is done the metal is likely to upset or warp. The heat should be confined to a dull red and fusion welding should be accomplished by two welders, one working on each side of the frame. Of course, it is necessary, prior to the erection of the furnace, to dismantle the adjacent parts just enough to enable the two welders to accomplish their work conveniently. The wheels are dropped before the work is started and any interfering parts removed.

Vanadium steel is recommended by some railroads for this work, while others recommend the use of nickel steel. Either one with proper reinforcement, by increasing the thickness of the section, will make a weld having ample strength. It is good practice to clamp a carbon block, on the bottom of the veed section, in order to form a convenient support upon which to begin the weld. The two torches, working simultaneously, prevent any distortion of the frame longitudinally and the preheating fire, in the fire-brick furnace, keeps the expansion of the lower part of the frame, B-C, at the correct amount, as welding progresses. When the job is completed, the weld is wrapped tightly with asbestos paper and the frame allowed to cool slowly and evenly until cold.

In some instances, it is possible to spread the weld sufficiently with jacks, or wedges, to take care of the contraction after the weld has been completed. An oxy-acetylene fusion weld, for a frame six inches by six inches in cross-section, will require an expansion of approximately five-sixteenths of an inch and this amount of expansion is extremely difficult to obtain by mechanical means. Preheating, as indicated in Figure 11, will expand the joint, A, sufficiently, but it is a good deal to expect of the lower part of the frame to spring it to this extent.

Electric and Thermit welding of frames will not be discussed, because this course is confined entirely to oxy-acetylene welding with the torch and it is sufficient that the welder learn the principles and characteristics of this process without attempting to study other methods.

Bronze welding of the frame eliminates the necessity for preheating to any such extent. In this case the preparation of the frame at A would be the same as heretofore described, but as it is not necessary to heat the top chord of the frame nearly so hot as in fusion welding, full expansion at B-C is not necessary. For this reason, the cost of bronze welding is much less than fusion welding and the result, as shown in Lesson No. 11 is a stronger joint. If desired, both the lower chord, B-C, and the joint at A can be preheated with a kerosene or fuel oil heater and as soon as a little more than a black heat has been reached, the preheaters can be removed, the lower chord, B-C, covered with asbestos paper and bronze welding immediately started at A.

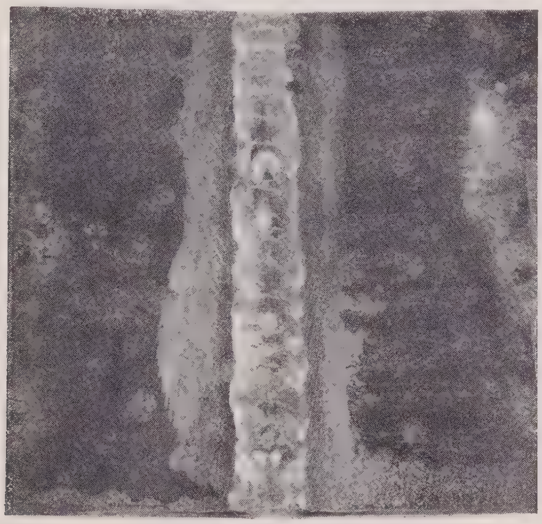


Figure 12—Photograph Showing Two Pieces of One-eighth Inch Steel Bronze Welded Together. Bronze Welding Steel Is a Process Utilized to a Great Extent in the Manufacture of Metal Furniture.

Two welders should be utilized as heretofore described and the surfaces of the vee tinned in the usual manner, using one-quarter inch Tobin Bronze welding rods and a flux similar to No. 3 A-Mal-Gam. The weld should be started at the bottom of the vee on top of the carbon block and built up section by section, as heretofore described. About two inches of the height of the weld should be tinned and then this section completely filled in until the full section has been built up. The next two inches should then be welded and so on until the entire depth of the frame has been completed.

As stated in Lesson No. 11, the contraction of a bronze weld in a four by five inch section may be as little as three-sixty-fourths of an inch. If it is no more than this, it will be appreciated that such an amount will not set up any very serious strains in the frame and, as a rule, bronze welding, therefore, does not present any difficult problems, relating to expansion and contraction.

Of course, practice in this respect will vary somewhat upon different railroads and in some instances the frame may be veed horizontally to an angle of sixty degrees and only one welder used to bronze weld the section. The method of preparation and the exact routine of the weld will depend upon the operator and upon the foreman in charge of the job. Most of the railroads have standard practice books which indicate how all such work shall be accomplished and these standard practices are, as a rule, lived up to by the welding crew.

However, as in all mechanical practice, there is a variation in methods caused by differences of opinions of engineers and by the local conditions at the shop where the work is being carried on. A welder going to work in a railroad shop will usually be given full instructions before proceeding with a job of this kind.

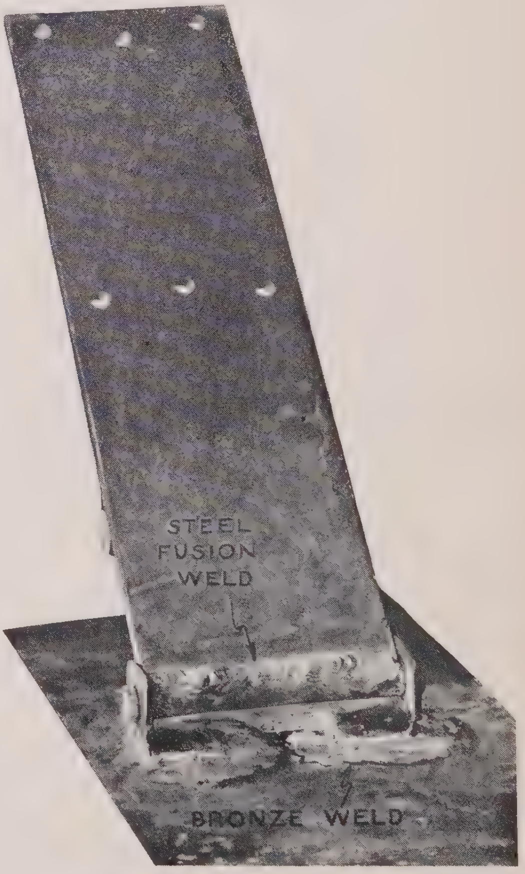


Figure 13—Photograph Showing a Bronze Welded Motor Base which Is Hinged to the Main Compressor Base in an Oil Burner. This Arrangement Is a Convenient Way to Maintain a Tight Belt.

Bronze Welding Steel

The principles of bronze welding steel and the procedure are almost identical with the bronze welding of cast iron, except that as a rule a different flux is used. The same grade of flux is ordinarily used for welding steel, as heretofore mentioned for welding malleable iron. The flux recommended is No. 3 A-Mal-Gam and it is what is often termed a brazing flux, principally because it is also used for brazing brass and copper.

Perhaps one of the best ways to be sure of the temperature required in bronze welding steel is to heat a small area of sheet steel to a very dull red heat and, after dipping the Tobin Bronze rod in the flux box, applying a small quantity of flux to the heated surface, to fuse a little of the Tobin bronze rod on the hot surface of the steel. In all probability at the temperature to which the steel has been heated, the bronze will not flow over the surface to tin it. The welder should next heat another spot in the sheet steel to a white heat and likewise apply flux and a little of the Tobin Bronze rod. It will be noted now that the bronze will flow over the steel, but will burn with a bluish flame, indicating that the zinc content of the bronze is overheated. If another spot in the steel plate is heated to a cherry red temperature, and flux and a little of the bronze rod applied to it, the bronze will flow out over the cherry red steel in clear, clean metal with a bright golden color. There will be no oxide upon its surface and the welder will have no difficulty in recognizing that this is the correct temperature at which the bronze will flow and tin to best advantage.

Figure 12 shows two steel sheets one-eighth inch thick bronze welded together. In this instance the sheets were placed close together, separated only by a scant thirty-second of an inch and heated with the torch to a cherry red. Flux was used, as heretofore described and the bronze tinned over the surface. A short distance was tinned and then the weld made to its full thickness of the ripple type. Another section was then tinned and the weld built up in the same manner, until finally, the weld was completed clear across its length. There is a great deal of sheet steel bronze welded at the present time, because the bronze weld can be applied quickly and without warping the steel. Steel cabinets, steel desks and office furniture, steel bedsteads, dressers, washstands and other similar bedroom furniture are almost all of them put together with internal bronze welds. That is, the bronze welds are made between the braces, brackets, and internal parts of the piece of furniture. Of course, these bronze welds do not show and wherever the joint is exposed, as it would be if it were an outside corner, the weld is made with steel and finished smooth with the surface.

Hinged Motor Support for An Oil Burner

An example of the convenience with which bronze welded joints can be utilized is the assembly of mechanical equipment illustrated in Figure 13. This photograph shows a hinged motor support for an oil burner. The object of this support is to furnish a base for an air compressor and a simple and efficient means for keeping the belt between the motor pulley and the fly-wheel of the compressor tight. There are a number of devices upon the market to accomplish this purpose, one of which includes an additional wheel mounted upon a hinged frame which idles on top of the belt. Such an arrangement, in this instance, would have been more complicated than the means shown supporting the motor upon a hinged base plate.

The shaft of the hinge has been made by welding a bolt to the piece of steel forming the motor base and by bronze welding two pieces of strap iron, bent at right angles, to the base of the compressor. Bronze welding is employed instead of fusion welding to join the angular steel brackets directly to the compressor base plate, because it is a quicker process and involves less heating than fusion welding. In this instance a flat surface of considerable area is to be joined to another flat surface, and if fusion welding were attempted, it would be necessary to weld all around the edges of the angular bracket. This would require more time and more heat and would buckle the base plate to a greater extent, than heating the steel and the bracket to a cherry red and bronze welding.

Job Sheet No. 12

Bronze Welding Cast Iron Plates

For the work to be done on this job sheet, procure several pieces of a good grade of cast iron, approximately six inches square, and one-half inch thick, some 3/16″ Tobin Bronze welding rod and a tip corresponding to a No. 5 tip assembly; besides this the regular equipment of oxygen and acetylene tanks, regulators, hose, torch, etc., will be needed.

In order to familiarize the student with the welding of cast iron with bronze, this lesson consists of bronze welding two pieces of cast iron plate together.

Prepare the edges of the two pieces so that when the edges are placed together a vee of approximately 90 degrees will be formed. This bevelling should be done preferably with a chipping hammer or a cold chisel and not with a grinding wheel. As explained in Lesson No. 11, the use of a grinding wheel makes the surface of the cast iron very difficult to tin. After the pieces have been properly bevelled, either anneal the edges to be welded or sear them with a torch as described in the previous lessons.

The pieces should then be lined up on a couple of fire bricks, the torch lighted and the surfaces of the bevel coated with flux similar to A-Mal-Gam No. 2 by means of dipping the end of the welding rod into the can of flux and then allowing the flux which adheres to the end of the rod to melt into the vee. After the vee has been covered with a coating of flux, the Tobin Bronze rod should be allowed to melt into the vee and spread out thoroughly tinning the surface.

After tinning the sides of the vee thoroughly proceed to fill in the vee. On short pieces, like these, where it is unnecessary to guard against expansion and contraction, it is generally good practice to start at one end of the vee and weld entirely across the crack filling the vee about half full. When the other end of the crack is reached, the motion of the torch is reversed and the weld completed, finishing at the point where the weld was first started.

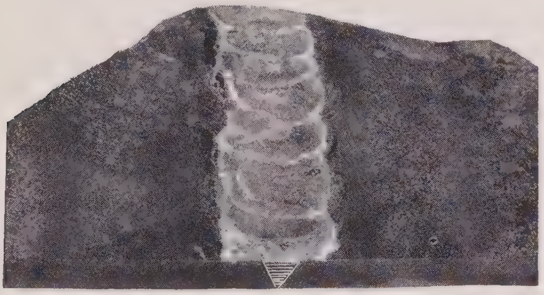


Figure 14—This Photograph Shows How the Two Pieces of Cast Iron Which are to be Welded Together in this Job Sheet should Appear After Welding. Note how Even the Surface of the Bronze Appears. The Front Edge of this Piece was Machined Down after Welding in Order to Show just How the Pieces of Cast Iron were Veed out Before Welding. The Outline of this Vee is Shown by the Light Section on the Front Edge of the Photograph.

There are several points which should be emphasized regarding the bronze welding of cast iron. These are:

1. The surfaces to be bronze welded should be clean and free from any scale or like material.
2. The surface of the pieces adjacent to the edges of the vee should be well cleaned off, so that the bronze after filling the vee, will spread out slightly to each side, thereby giving a slight additional surface for the bronze to cling to.
3. The sides of the vee must be well coated with flux down to the very bottom of the vee. If this is not done the flux will adhere only to the points that have been well fluxed and a weak weld will result.
4. The metal must be hot enough to cause the bronze to flow freely and yet not hot enough to burn it. The heat of the piece should be controlled by moving the luminous cone closer to the piece or farther away from it. If the piece is too cold, the bronze will have the appearance of being plastered onto the piece, while if the bronze gets too hot, excessive white fumes will rise from it, indicating that the bronze is being burned.
5. After the weld has been completed, do not plunge it suddenly into a cooling solution, but allow it to cool off naturally. A bronze weld should not be made to withstand any strain until it has become thoroughly cold.

After the pieces have been bronze welded together, place the piece in a vise so that the edge of the bronze weld is just even with the jaws of the vise and facing the welder. Now take a hammer and strike the upper portion of the piece, bending it away from the front of the vise. If the weld is well made, the cast iron piece should break somewhere outside of the weld. However, if the bronze did not adhere firmly to the cast iron, the piece will pull away from the bronze. If the bronze was burned during the application, it will have little strength and the weld will break through its center.

Note any defects in the weld that are shown up by its breaking and then bronze weld two more pieces of cast iron together remedying any of the defects which may have been noted. The student should continue making bronze welds until he is able to make a weld that will hold satisfactorily.

Questions:

1. What is malleable iron?
2. How is it made?
3. Why should bronze rods be used to weld malleable iron castings rather than cast iron or steel rods?
4. What effect has the use of bronze upon the expansion and contraction?
5. What differences are there between manganese bronze and Tobin Bronze?
6. What effect has a grinding wheel upon a surface to be bronze welded?
7. What is the purpose of searing and annealing cast iron to be bronze welded?
8. Why is the punch press frame, illustrated in this lesson, preheated?
9. How many pounds of Tobin Bronze rods will it take to weld together two pieces of cast iron one and five-eighths inches thick and eight inches wide? The edges of the pieces are bevelled to a single 90-degree vee.
10. How many pounds of Tobin Bronze will be required if the work in question 9 is double veed?

Lesson No. 13

The Business Side of Welding

IN the lessons heretofore the technique of welding has been thoroughly discussed, but nothing has been said about welding as a business proposition. In Lesson No. 13 this subject is given careful consideration, while the job sheet continues with the bronze welding process and the specific work is bronze welding sheet steel. Many more bronze welding jobs could be described, as was done in Lesson No. 12, but the general methods of procedure in all of these jobs would be relatively the same, and the description would be largely a repetition of what has already been written.

General rules and regulations have been set forth for bronze welding and the principles carefully explained. If these principles are followed, and expansion and contraction given careful consideration, almost any job will be found to resolve itself into the same general procedure. For this reason Lesson No. 13, insofar as the text is concerned, is confined to the subject welding from a business point of view.

The blacksmith shop, the garage and the welding shop buy welding and cutting equipment because it gives them the means with which to make more money. The industrial plants and the railroad shops install welding and cutting equipment because it will save money for them. In the first instance, the work accomplished by the outfits is being sold to the public. In the second instance, money is saved by repairing machinery when broken, by reclaiming defective parts in the manufacture of machinery and by utilizing the process in manufacturing production work. The result is lower operating or repair costs and hence a saving of money.

There is considerable difference in these two uses of equipment, for the shop owner, who sells the product of the welding apparatus to the public, has many problems to contend with which are not met with in manufacturing plants. The shop owner must sell this product at a price which the public is willing to pay and at the same time make a profit. Furthermore, he must often compete with other shops, in his locality, which may not be doing as good work as the shop in question and which may be charging a lower price. Moreover, a competing shop may not have any accurate means for determining the cost of work and may be selling repairs at a price which will not normally enable it to make a profit. All of these conditions can be successfully met if accurate methods are used to determine the actual cost of various jobs as they pass through the shop.

The job shop or blacksmith shop making it a practice to charge an arbitrary price for welding, which is guessed at rather than determined by actual cost, is almost certain to find in the long run that one customer is being charged a very high price for work done, while another customer is being charged a price which is much less than the job is worth. Perhaps both customers are being charged too little with the result that the job shop will loose money and may eventually go out of business. For these reasons, every shop manager should give very careful attention to determining the accurate cost of every job and to adding to these costs a proper percentage for overhead.

Overhead Explained

Overhead is a word which many men do not understand. It is a simple word, but in most instances it means a good deal and for this reason it will be carefully analyzed in this lesson. The overhead of a shop is the additional cost of operating the shop in excess of the actual labor and material which is utilized to accomplish the productive work of the shop. By productive work is meant that work which yields an income.

For instance, suppose that the shop in question is operated by a shop owner, that he has one girl in the office to answer the telephone and to write letters, keep books, etc., and that he has three welders in the shop. The items of expense which must be charged against each job in order to make that job profitable are rent for the building, or if the building is owned by the shop owner, taxes, repairs, insurance and general upkeep. The building must be heated in the winter and the cost of heating must be charged to the general cost of which we are speaking. Other costs are telephone, telegrams, stationary and postage and other incidental office expenses, as well as the salary of the office girl and the salary which the shop owner allows himself in return for his services. Furthermore, there must be adequate amounts allowed for interest on the invested money, for employers liability and other insurance, for amortization or charging off the cost of equipment which will wear out, for bad debts which cannot be collected, and for idle time which is discussed later in the lesson. If there is a delivery truck a sufficient amount must be included for this service. Delivery can be charged for, if desired on each job card, but there is usually considerable such expense which must be charged to overhead.

If these items are all added together for a period of one month, it will be found that they amount to a considerable sum. Suppose it is assumed that the shop is doing, on an average, fifteen jobs a day. These various items amounting to a fixed sum each month must be prorated, or distributed, over each of these jobs in order to be sure that all of the items of expense of operating the shop are taken care of. There must be some easy way in which this amount can be apportioned properly to each job; the shop without a system will often incur loss because each customer does not pay his just proportion of this fixed expense.

It should now be perfectly clear to the student just what is meant by overhead. Ordinarily overhead is paid by adding to each job a percentage based upon the cost of labor required for each job. This is the fairest way in which the item of overhead can be charged up and it is usually accomplished in this manner in most manufacturing plants.

The cost of each job is represented by the amounts of oxygen, acetylene, welding rods, flux, and any charcoal, kerosene, asbestos paper, carbon blocks, pieces of steel or other metals which are used in connection with the job. These items are all the material items which enter into the cost of the work. It may require more or less time to accomplish the job and the time of the welder represents the productive labor of the shop. There are three welders in the shop, used as an example, and it has already been assumed that the average number of jobs passing through the shop are fifteen daily. Therefore, each welder would, in all probability, do five jobs, although some jobs might be larger than others and it might be that one welder would be confined entirely to one job for the whole day, while the other welders would take care of the rest.

However that might be, each job requires a certain number of hours of the welder's time and if there are three men in the shop and the shop is working on a nine hour basis, there would be twenty-seven hours of labor upon which the overhead could be charged. There are on an average, twenty-five days in each month and the monthly overhead charge should be divided by twenty-five to establish a daily overhead charge which should be divided by twenty-seven hours to give an hourly overhead charge. Therefore, this hourly overhead charge would have to be added to the cost of the material and the welder's wages, in order to get the total cost per hour for the job. Usually this overhead charge is figured on a percentage basis.

After a little figuring it may be found, for instance, that the cost of overhead is about 150 per cent of the productive labor. This is an easy way to figure it, and if properly apportioned and added will give fairly accurate results. In some shops the cost of overhead might not be more than 100 per cent, and in this event, the cost of labor, including overhead, on a particular job, would simply be double the productive labor charge.

There are a great many welding shops operating at the present time without any definite overhead figures; these shops rely solely upon the adding of an arbitrary sum of money to the cost of the job in order to include enough to pay these various items and yield a profit. It will be realized, however, that this method is just a guess and is really not a satisfactory, nor a sure way of taking care of the items which are not directly charged to the job.

Perhaps the best way in which these charges can be taken care of, is by the establishment of a cost system in the shop which, in a simple and effective manner, enables the shop owner to keep accurate record of his costs for all work passing through the shop.

A Simple Cost System Necessary

It is always essential that a system in a small shop be as simple as possible and involve the least amount of red tape. If the system is complicated, it is not lived up to and it becomes a burden, rather than a benefit. The first step in developing a system of this kind is to determine a means for finding out how much oxygen and how much acetylene is used on each job. Oxygen is always procured in cylinders and it is, therefore, very easy to determine the amount of oxygen used upon each job.

Acetylene, on the other hand, whether in cylinders or used from a generator, is not easy to figure, and for this reason, it is ordinarily best to base the amount of acetylene consumed upon the amount of oxygen. If several welders are using the acetylene from a pipe line from a generator, it will be readily appreciated that it would be almost impossible to tell how much acetylene each was consuming, unless a very careful record was kept of the tips in use, and the time each was operated, and even this would be a difficult matter. Similar conditions would exist if acetylene cylinders were used, because gauge pressures are not accurate enough for the computation of acetylene used from a cylinder and it would be necessary to weigh the cylinders to determine accurately the volume of acetylene used from them.

This, of course, is out of the question in the average shop and for this reason the simplest method for determining the acetylene consumed is to assume that it is equal to the oxygen consumption. This is sufficiently accurate for all practical purposes, but the cost of the acetylene must be based upon whether it is produced in an acetylene generator from carbide, or whether it is obtained in cylinders. If the acetylene is generated in an acetylene generator, the cost will equal the cost of the carbide consumed, the cost of water used in the generator and the labor necessary to recharge the generator. Under normal conditions this cost will be found to be approximately one and one-quarter cents per cubic foot of acetylene.

On the other hand, if acetylene is delivered to the shop in cylinders, the cost will vary with the locality in question, where the acetylene was purchased and whether or not the cylinders are loaned to the customer. In some instances, cylinders are sold to the customer on an exchange agreement basis, and while they are not his property, he has the right to use them. In other instances, the cylinders are sold outright to the customer and become his property. The cost of acetylene varies with the conditions of sale. This cost may be from three to four cents per cubic foot, depending upon these conditions.

The cost of oxygen, on the other hand, is more definitely known because in almost all instances oxygen cylinders are loaned for a period of thirty days. Often there is a rental charge upon cylinders, retained in the shop for a period of longer than thirty days, but ordinarily the shop owner who uses any quantity of gas can easily return the cylinders within this period and if he does so he avoids any rental expense.

The cost of oxygen may range from two cents to three cents per cubic foot, depending upon location and quantity consumed. Of course, in stating these general figures for these gases, the freight and delivery charges have been included. The invoice for the oxygen may be at lower prices than those mentioned, if large quantities are used, but it must be remembered that freight must be paid, if the shop is located on the railroad some distance from the oxygen plant, and the cost of trucking to and from the freight station must also be included. Of course, if a shop is located in a larger city, within the free delivery zone of an oxygen plant, such charges need not be considered.

It is important, however, that the shop owner determine the accurate cost of both oxygen and acetylene delivered in his shop, if procured in cylinders and the accurate cost of acetylene in the pipe line, if produced in a generator. When these facts are known, it is a very simple matter to apply these figures to the number of cubic feet of both gases, based upon the oxygen consumption, determined from the gauge readings of the cylinder. To determine the volume of oxygen in a cylinder under a given pressure, Chart No. 5, page 29, Lesson No. 3, will be found very convenient, and in order to simplify this chart, the following table is reproduced from it, giving the amount of oxygen in a cylinder at various pressures at a temperature of 70-degrees Fahrenheit. For all practical purposes in determining the number of cubic feet in a cylinder, this table will suffice.

If a copy of this table is made and placed on the shop wall, the welder can very quickly determine how much oxygen he has used upon a certain job. The table, of course, refers to 220 cubic foot cylinders of oxygen, which are of standard size, and if the small cylinders, containing 110 cubic feet are in use, the amount should be divided by two. If, for example, at the beginning of a job the oxygen cylinder is full and at the end of the job there is 500 pounds pressure in it, there would be remaining in the cylinder approximately

Approximate Table Giving the Nearest Even Cubic Foot of Oxygen Contained in a Standard 220 Cubic Foot Cylinder for Each Twenty-five Pounds Gauge Pressure

Pressure in Cylinder lbs. per sq. in. at 70° Fahr.	Cubic Feet at Pressures Given	Pressure in Cylinder lbs. per sq. in. at 70° Fahr.	Cubic Feet at Pressures Given	Pressure in Cylinder lbs. per sq. in. at 70° Fahr.	Cubic Feet at Pressures Given
0	0.00	675	74	1350	148
25	3	**700**	77	1375	151
50	5	725	79	**1400**	154
75	8	750	82	1425	157
100	11	775	85	1450	159
125	14	**800**	88	1475	162
150	16	825	90	**1500**	165
175	19	850	93	1525	168
200	22	875	96	1550	170
225	25	**900**	99	1575	173
250	27	925	101	**1600**	176
275	30	950	104	1625	179
300	33	975	107	1650	181
325	35	**1000**	110	1675	184
350	38	1025	112	**1700**	187
375	41	1050	115	1725	190
400	44	1075	118	1750	192
425	46	**1100**	121	1775	195
450	49	1125	123	**1800**	198
475	52	1150	126	1825	201
500	55	1175	129	1850	203
525	57	**1200**	132	1875	206
550	60	1225	134	**1900**	209
575	63	1250	137	1925	212
600	66	1275	140	1950	214
625	68	**1300**	143	1975	217
650	71	1325	145	**2000**	220

It Will be Noted that, in a 220 Cubic Foot Cylinder of Oxygen, each Increase of Approximately 9 Pounds of Pressure Increases the Volume of Oxygen in the Cylinder 1 Cubic Foot.

fifty-five cubic feet, or the consumption would be 220 cubic feet minus fifty-five, or 165 cubic feet of oxygen consumed. As the acetylene consumption is equal to the oxygen, there would be 165 cubic feet of acetylene consumed. To this should be added the welding rods, flux, asbestos paper, and any other items or material which are chargeable against this job. Often 10 per cent is added to the invoice cost of material to cover handling charges, etc.

Customer's Check No. 27358

Description of Job..........

....

....

Price Quoted..........

Date Promised..........

Identification Tag No. 27358

○ Metal Tag..........

Name..........

Job..........

....

Date Rec'd..........Date Promised..........

COST CARD No. 27358

Name..........

Address..........

Date Rec'd.......... Delivered..........

Article..........

Make full description on reverse of card.

....

Welder..........

Welder's Time..........hrs. at..........cost..........

Helper's Time..........hrs. at..........cost..........

TOTAL labor cost..........

Preheating Fuel..........at..........cost..........

Oxygen..........cu. ft. at..........cost..........

Acetylene

Generated..........cu. ft. at..........cost..........

Cylinder..........cu. ft. at..........cost..........

Welding rod..........lbs. at..........cost..........

Miscellaneous Items:

..........cost..........

..........cost..........

TOTAL labor and material cost..........

Price Quoted	OVERHEAD - ....% Labor..........
	TOTAL cost - - - - ....
	..........% Profit - - - ....
....	Am't. to be charged - - - ....

Figure 1—A Handy Combination Job Card Consisting of a Customer's Claim Check, an Identification Tag and a Cost Card Combined. These Cards Should be Made Up, so that the Size of the Cost Card is Four Inches Wide and Six Inches Long, which is a Standard Size and can be Filed in a Standard Filing Cabinet.

The labor should also be computed at the rate paid the man plus the percentage allowed for overhead. To this amount should be added a fixed percentage to cover profit. This final amount is the selling price. The amount allowed for profit should be ample to pay the shop owner a proper return, based upon the fact that he is operating a highly specialized business which requires considerable expert knowledge and where the work is seasonable.

Repair Work Is Not Usually Steady

The fact that repair work is not always steady is one of the difficult features of a welding shop. It is usually either a feast or a famine, for the shop may be rushed with work one week and idle the next. It is true that in the overhead an allowance has been made for idle time and this allowance is based upon the experience of the shop in that locality, but even so, the amount allowed for profit should be sufficient to provide an adequate return considering the class of equipment in which the money is invested.

Weights of Round Steel Welding Rods

Diameter in Inches	Pounds Per Foot	Feet Per Pound	Approximate Number of 36-inch Rods in 50-lb. Bdle.
$\frac{1}{16}$	0.010	96.154	1,600
$\frac{3}{32}$	0.023	42.735	700
$\frac{1}{8}$	0.042	24.038	400
$\frac{5}{32}$	0.065	15.376	250
$\frac{3}{16}$	0.094	10.672	175
$\frac{7}{32}$	0.128	7.837	125
$\frac{1}{4}$	0.167	5.999	100
$\frac{9}{32}$	0.211	4.739	75
$\frac{5}{16}$	0.261	3.831	70
$\frac{3}{8}$	0.376	2.660	45

An allowance in the overhead must be made for idle time, because there will be a part of the time of the welder during which he has nothing to do and is not productive. He, of course, can straighten out the shop, make shop repairs and do other work during this period, but while he is improving the shop, his time is not earning an income and must be accounted for in some way. For this reason, a suitable allowance for this idle time must be made and charged against every job which goes out of the shop; this is accomplished by including this amount in the overhead.

It should be the object of every shop owner to obtain some welding work, which is steady in volume, with which he can fill in the idle time of his men in the shop. There are certain items which can be welded and sold at a profit and if the shop owner is alive to the opportunities of his job, he will be constantly on the lookout for work of this nature, either for another concern located in the district, or for some article which he can make and market at a profit. The success of the job shop is dependent largely upon the efforts of the owner along these lines. If he can keep all of his men in the shop busy all the time, at a profit, he can operate a very successful business that will grow. If, however, he is dependent entirely upon the repair work which comes in to him and that which he himself goes out and contracts for, he will find that there is so much fluctuation in this work, in most territories, that he cannot keep all of his men busy all of the time and this loss prevents him, in the long run, from operating a business which is as successful as it might be.

A Successful Cost System

It is, of course, necessary in figuring the cost of jobs in this manner to have various cards and other forms arranged and printed for the purpose, so that the bookkeeping and general accounting will be simplified. A good system which has been utilized in many shops and is probably as successful as any is described herewith. In Figure 1 a convenient form of claim, identification tag and cost card combined is illustrated. When a job comes into the shop one of these combination tags is attached to the job after the customer's name and address, the description of the article, the date received, the date promised and the price quoted have been noted upon both the claim check and the identification tag.

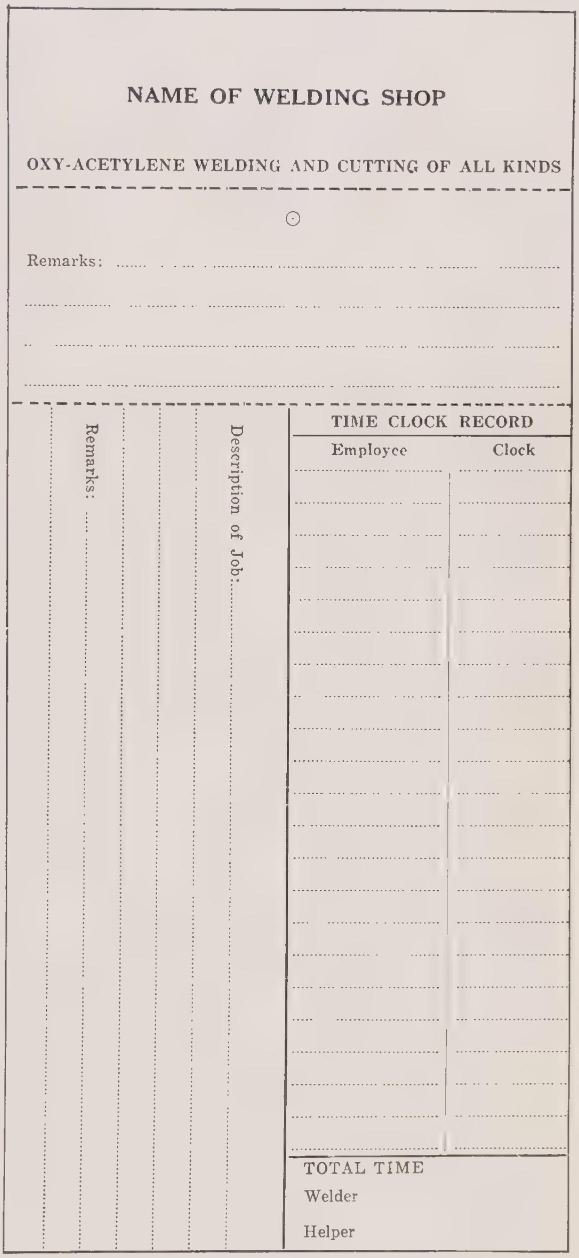
Weight Per Foot of Cast Iron Welding Rods of Various Sizes and Shapes

Size in Inches	Square	Round	Hexagonal
3/16	0.110	0.086	0.095
¼	0.195	0.153	0.169
5/16	0.305	0.239	0.264
⅜	0.437	0.344	0.380
½	0.780	0.613	0.676

The claim check is torn from the balance of the form and given to the customer. The identification check is wired to the casting and the record form is handed to the welder who is to do the job. The casting is then sent to the incoming jobs pile to be repaired. The welder places the card in a box or a drawer of jobs which he has to do and just as soon as he has the opportunity he matches up the number on the card with the identification card attached to the casting in the incoming jobs pile, removes the identification tag, substitutes a metal tag bearing a number and notes this number on the identification tag. The metal tag will not burn up during preheating or welding and only about twenty metal tags are necessary under ordinary circumstances. The welder places the identification tag in his drawer or box and will later replace it upon the casting, after removing the metal tag, when the casting is cold.

He keeps a record upon a page of his note book of the amount of oxygen and acetylene used; the charcoal, kerosene, or fuel oil consumed for preheating; the welding rods, asbestos paper, carbon blocks or other materials used in connection with the job and the number of hours of labor upon it. When the job is finished, these figures are all completed by him and noted upon the card form.

If a time clock is used in the welding shop to keep track of the time spent on each job, the back of the record card may be used for the clock imprints as shown in Figure 2. The card is turned over, slipped into the time clock and the time punched thereon. This is, in reality, the most accurate and convenient way in which the time on each job can be kept, but sufficient accuracy may be obtained, for all practical purposes, by merely noting the time on the card in pencil. If



NAME OF WELDING SHOP

OXY-ACETYLENE WELDING AND CUTTING OF ALL KINDS

Remarks:

Remarks:

Description of Job:

TIME CLOCK RECORD

Employee	Clock

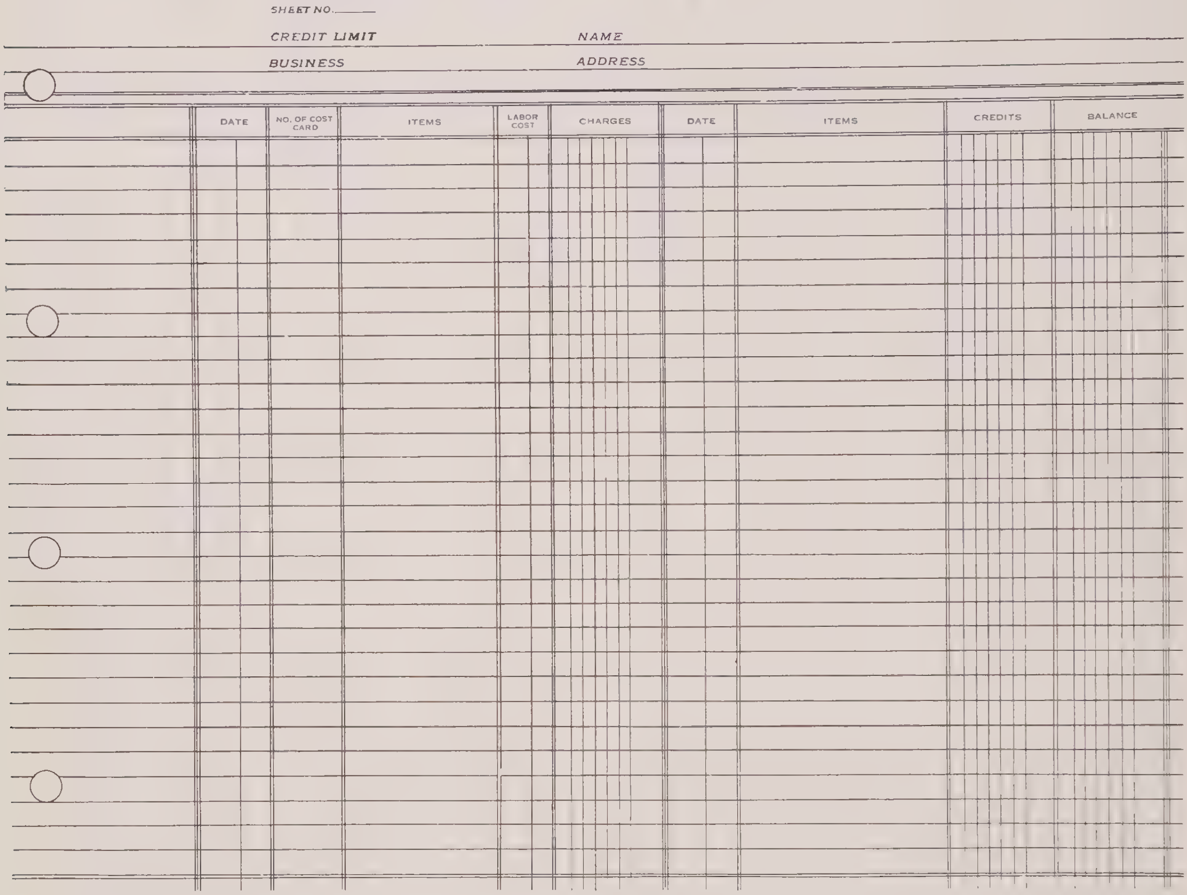
TOTAL TIME

Welder

Helper

Figure 2—This Illustrates the Opposite Side of the Card Shown in Figure 1, Indicating the Space Allowed for the Imprint of a Time Clock, if Such is in Use. There is also Space on this Side of the Card for Additional Notations If Required.

the welders are careful in this respect, there need be no confusion and the time may be just as accurate as if a time clock were installed. The identification tag is then placed upon the piece, it is put in the pile of completed jobs ready for delivery and the welder turns the card into the office.



SHEET NO.

CREDIT LIMIT NAME

BUSINESS ADDRESS

DATE	NO. OF COST CARD	ITEMS	LABOR COST	CHARGES	DATE	ITEMS	CREDITS	BALANCE

Figure 3—A Convenient Form of Ledger Sheet for Use in a Welding Shop.

The office girl takes the card, figures the cost of all items noted on it, and adds the normal overhead and profit which gives her the correct charge which should be made. This she enters on the ledger sheet of the customer and notifies the customer that the job is ready for his pick-up, or notifies the shop truck that it is ready for delivery. When the entry is made in the ledger an invoice is made at the same time to be mailed to the customer, or if it is a C. O. D. or cash job, it is dealt with accordingly. This system is very simple and if properly handled will absolutely assure the shop owner that a profit is made upon each job.

If an estimated price upon a job must be given, when it is delivered by the customer, this price is noted at the time in the space indicated for it and this amount collected from the customer, or invoiced to him if he has a charge account. In the case of a price given in advance, in this manner, the profit may be more or less, depending upon the accuracy of the estimated price made at the time the job was taken. Record cards of this kind will be useful, not only in assuring that all costs are charged against each job, but will be a valuable means for estimating future jobs. If the description is adequately given upon the card, the shop owner can a year later estimate very closely the cost of a job which he has in view by referring back to a similar job which he knew was done six months or a year previous. While there is not a great deal of similarity in many repair jobs, others are almost identical, or if not identical so close to it that the cost of doing the work would be no more in one instance than in another.

Losses Easily Determined

Another valuable feature of a card system of this kind lies in the fact that the shop owner can immediately determine any losses which may occur. Loss will show up on a particular job and will mean that in the future, when he contracts for a job of this kind again, he must increase his price or else lose money a second time. Furthermore, this record is constantly before him in estimating upon future work and any loss can be kept track of by placing the card upon which a loss was made in a separate card file, under losses, and referring to this file with sufficient frequency so that when a similar job comes up again, the shop owner or the office girl will recognize it.

Accurate knowledge of costs, which must result from such a system as this, enables the shop to know, from day to day and week to week, what the profits are. It also sets an example for other shops in the vicinity. If for instance, three competing welding shops in a district cause a reduction in prices to such an extent that there is no profit in the welding business for any of the shops, a very serious situation has arisen where all three shops will lose money and one or two of them must eventually go out of business.

Table Showing Gas Consumption, Length of Flame, Regulator Pressures, Etc., for Each Size of Tip Assembly

Size of Tip Assembly	Thickness of Metal in Inches	Length of Ave. Flame in Inches	Approximate Pressure at Regulators in Pounds per Square Inch		Main Port Drill Size	Dia. of Main Port in Inches	Approximate Cu. Ft. of Gas Used per Hour		Approx. Number of Lineal Feet Welded per Hour	Size of Tip Assembly
			Oxy.	Acet.			Oxy.	Acet.		
1	$\frac{1}{16}$	$\frac{3}{16}$	1	1	63	.037	5.0	5.0	13.0	1
2	$\frac{1}{16}$ to $\frac{1}{8}$	$\frac{1}{4}$	2	2	58	.042	6.0	6.0	18.5—5.8	2
3	$\frac{1}{8}$ to $\frac{3}{16}$	$\frac{5}{16}$	2	2	54	.055	9.0	9 0	12.0—3.0	3
4	$\frac{3}{16}$ to $\frac{1}{4}$	$\frac{3}{8}$	3	3	52	.0635	12.0	12.0	10.2—3.5	4
5	$\frac{1}{4}$ to $\frac{3}{8}$	$\frac{7}{16}$	4	4	48	.076	21.0	21.0	8.3—7.5	5
6	$\frac{3}{8}$ to $\frac{1}{2}$	$\frac{15}{32}$	5	5	44	.086	23.0	23.0	4.2—2.3	6
7	$\frac{1}{2}$ to $\frac{5}{8}$	$\frac{1}{2}$	6	6	40	.098	36.0	36.0	3.1—2.0	7
8	$\frac{5}{8}$ to 1	$\frac{9}{16}$	7	7	36	.1065	50.0	50.0	2.1—1.7	8
9	1 and over	$\frac{5}{8}$	8	8	32	.116	58.0	58.0	Variable	9
10	Heavy Castings, Etc.	$\frac{3}{4}$	9	9	28	.1405	100.0	100.0		10
11		$\frac{3}{4}$	10	10	26	.147	106.0	106.0		11
12		$\frac{3}{4}$	11	11	25	.1495	108.0	108.0		12

This is an unfortunate situation for a community, because in many instances, it is necessary that the three shops be in existence in order to give the public the service which they are entitled to. Ordinarily prices, which are so low that money is lost in doing the right kind of a job, lead to the lowering of the grade of work done and, eventually, the consumer suffers because of these low prevailing prices.

Low Prices Usually Quoted Because of Ignorance of Costs

Usually a shop owner, who quotes a price to his customers which is too low to allow him to do good work, does it because of ignorance of the actual cost of the job and not because it is his intention to lose money on this particular work. Every man in business wants to make a profit, if he is a normal man, and he is entitled to a profit. On the other hand, the majority of consumers are perfectly willing to pay a profit in order to get a good article, or to have a repair properly made. The difficulty lies in the fact that, through lack of experience, the welding shop owner does not know what his actual costs are, with the result that he charges less in the belief that he is actually making money, whereas if he were including all of his costs, he would find that he was losing money instead of making it.

In an instance of this kind, it would be far better for the three shop owners to get together and interchange information so that all of them might have the data necessary to enable them to figure their costs adequately. It is to be expected that, with an accurate knowledge of costs, none of the shops in the community would willingly sell their product without a profit. Of course, an agreement on the part of three shop owners, upon a selling price might constitute a breach of the anti-trust laws, but there is nothing in the federal laws which prevent the common interchange of information with reference to costs and there is no necessity for an agreement insofar as the selling price is concerned.

One of the shops may consider that it is entitled to a little more profit than the others, because of greater investment or better equipment, but none of them would willingly sell even repair work at a loss. If costs are accurately known in a given district, all shops are more likely to prosper, to do better work and to give more efficient service. The community at large will be better off than if cut-throat competition prevailed.

Estimating the Cost of a Job

One of the difficult things which every shop owner encounters, in the early part of his experience, is estimating the cost of doing work. In many instances the owner demands that the cost of the job be given to him, or quoted to him, before the work is undertaken. In a great many cases, in the beginning of his experience, the shop owner will find that such an estimate is merely an intelligent guess as to what the cost will actually be. As he proceeds with such work and keeps careful records, such as those illlustrated, he will soon find that he has the basis for accurately estimating these costs.

There are very few figures which can be given about the cost of welding broken castings, because almost every break differs, the cost of preheating varies to a considerable extent and the amount of welding required is almost never the same. On the other hand, to attempt to estimate the cost by a fixed cost per square inch, or cubic inch, of metal in the weld, would be more likely to result in false figures than to be of benefit. In looking over a job, the shop owner must first determine how much time the job will take. This is the most important item and the accuracy of his guess in this connection will determine the accuracy of the estimate. This time must be split up into time for preparation of the casting, time for preheating and time for actual welding.

When these three figures have been estimated with fair accuracy, the rest of the estimate becomes comparatively easy. If the number of hours for preparing a casting is known, it is a simple matter to figure the cost whether the work done is with a hand chisel, a portable grinding wheel, or an air chipper. The same conditions apply to preheating, because the amount of charcoal, fuel oil, or kerosene can be quickly determined, based in a rough way upon the time required for the work. The consumption of oxygen and acetylene can also be based on the time and the size of tip. Reference to the table on page 15, Lesson No. 2, will give the consumption of each size of welding tip in cubic feet per hour and for convenience this table has been reproduced in this lesson. It then becomes a relatively simple matter to determine the amount of oxygen and acetylene required. The number of pounds of welding rod required for a given length of seam are shown in a table on page No. 181, Lesson No. 12, and the other items of expense, including asbestos paper, carbon blocks, etc., can be estimated with sufficient accuracy.

There is another item which enters into the cost of work of this kind and this is a very difficult one to estimate. This item is the wasted time required in case there is any delay on the job. The welders time is more likely to be wasted on outside contract work, where there are other tradesmen employed who must work in conjunction with him.

For instance, not so long ago, a refrigeration piping system was to be placed in an apartment building. The city welding shop is often called upon to bid upon such work and in this instance a shop took over the job at a fixed price per joint. The piping system was not a large one, and conveyed brine from a refrigerating system in the basement of the building up to the refrigerator outlet in each apartment. Three inch pipe was used in the basement for the main header, but the risers were of two inch pipe and the outlets to the refrigerators one-half inch.

There were no complications about this job so that the cost of welding each joint was easily estimated, but the unknown factor was whether or not the welder who was sent to accomplish this work could work at it continuously or would be delayed by other workmen, because their part of the building was unfinished. This is a consideration which must be taken into account in doing contract work.

The Job Shop Should Be the Local Welding Contractor

The job shop should normally be the local welding contractor for the district and if a shop owner is alert, he will endeavor to make his shop occupy this position. The use of welded joints, in connection with heating systems and plumbing, in buildings, is increasing throughout the country and is rapidly becoming a very important part of the welding industry. It is true that many plumbing concerns and many steamheating contractors will purchase welding and cutting equipment and teach their own men to do this work. However, in many cases, there is not enough continuous work to warrant these contractors in installing their own equipment and in such instances they will rely upon the local job shop to do the work for them.

In similar manner there are a considerable number of industrial plants where the work is limited and, in the opinion of the officials, not sufficient to warrant the purchase of welding equipment. These concerns, too, must rely upon the local shop and there is no reason why this class of work should not constitute a very considerable proportion of the welding done by the shop owner. There is no reason why he should operate his shop for repairs only, and feel that he is not qualified to go out and obtain this other class of work, which is often steadier and more profitable than the repair work of the district.

The same remarks apply to obtaining production work from industrial concerns in the neighborhood. Welding is a specialty and if the shop owner goes out to sell his services or the services of his men to small industrial plants, he is likely to find some production job, like the welding of small tanks, the welding of certain pieces of pipe, or the reclaiming of castings which prove defective, or some other work of like nature, which will fill up the gap in his shop caused by the fluctuation in volume of the repair business.

The Importance of Good Welding

Every business is based to a large extent upon repeat orders. A business selling only one of an article, with which the customer is ultimately dissatisfied, is not working upon a plan which will continue to assure success. In a welding shop it is particularly important that every job welded be successful if it is possible to make it so. It is obvious that if a customer brings a part to a shop to be welded, and the welder makes a poor job of the weld with the result that it breaks after being placed in service, the customer is not likely to bring it back again to that shop. He will conclude, of course, that that particular shop does not know much about welding and for that reason he will usually take the second job to a competitor who, he hopes, knows more about it.

It is, therefore, important from a business point of view that every job which leaves a shop should be made as strong as possible and that the shop owner should assure himself that the work has been done as well as it is possible to do it. Even a low price is not a reasonable excuse for poor work. It would be better business if

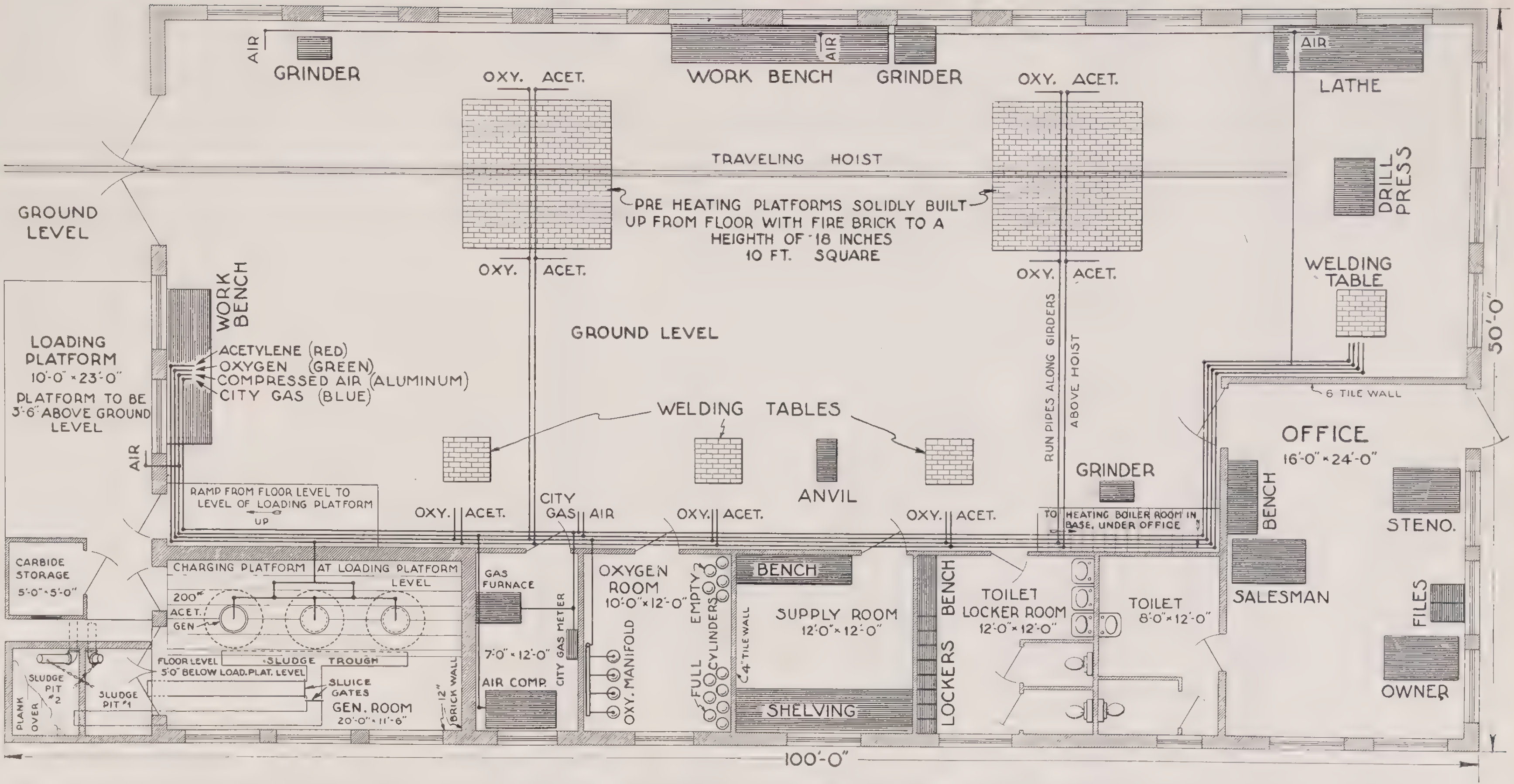

50'-0"
100'-0"
AIR
GRINDER
WORK BENCH
AIR
GRINDER
AIR
LATHE
OXY. ACET.
OXY. ACET.
TRAVELING HOIST
DRILL PRESS
GROUND LEVEL
PRE HEATING PLATFORMS SOLIDLY BUILT UP FROM FLOOR WITH FIRE BRICK TO A HEIGHTH OF 18 INCHES 10 FT. SQUARE
OXY. ACET.
OXY. ACET.
WELDING TABLE
WORK BENCH
LOADING PLATFORM 10'-0" × 23'-0"
PLATFORM TO BE 3'-6" ABOVE GROUND LEVEL
ACETYLENE (RED)
OXYGEN (GREEN)
COMPRESSED AIR (ALUMINUM)
CITY GAS (BLUE)
GROUND LEVEL
RUN PIPES ALONG GIRDERS
ABOVE HOIST
6 TILE WALL
WELDING TABLES
OFFICE 16'-0" × 24'-0"
AIR
GRINDER
RAMP FROM FLOOR LEVEL TO LEVEL OF LOADING PLATFORM
UP
OXY. ACET.
CITY GAS
AIR
OXY. ACET.
ANVIL
OXY. ACET.
TO HEATING BOILER ROOM IN BASE, UNDER OFFICE
BENCH
STENO.
CARBIDE STORAGE 5'-0" × 5'-0"
CHARGING PLATFORM AT LOADING PLATFORM LEVEL
200#
ACET. GEN
GAS FURNACE
OXYGEN ROOM 10'-0" × 12'-0"
EMPTY
CYLINDERS
FULL
BENCH
SUPPLY ROOM 12'-0" × 12'-0"
4" TILE WALL
LOCKERS
BENCH
TOILET LOCKER ROOM 12'-0" × 12'-0"
TOILET 8'-0" × 12'-0"
SALESMAN
FILES
OWNER
7'-0" × 12'-0"
CITY GAS METER
OXY. MANIFOLD
AIR COMP.
SHELVING
FLOOR LEVEL 5'-0" BELOW LOAD. PLAT. LEVEL
SLUDGE TROUGH
SLUICE GATES
GEN. ROOM 20'-0" × 11'-6"
12" BRICK WALL
SLUDGE PIT #1
SLUDGE PIT #2
PLANK OVER

Figure 4—Plan of a Typical Welding Shop. This is a Fully Equipped Shop for a Medium Sized Town. Smaller Shops may be less Elaborate and Arranged to Suit the Building Available. The Object in Making this Floor Plan is to Show the Student What an Ideal Shop Arrangement should be. As a rule, Automobiles for Ordinary Repairs are Driven into the Shop. The Door at the Rear is Large Enough and there is Sufficient Space in the Shop to Accommodate Several Machines. The Traveling Hoist is Supported from the Roof Girders or if These should be too Weak in an Existing Building, Supporting Posts and I Beams could be Used for the Purpose.

the shop owner did a good job even if he lost money, because under these circumstances he has every reason to expect that the future business of his customer will be brought to his shop and that he will have an opportunity to make up his loss. Even if he never made up the loss, the reputation gained by square dealing will, in the long run, win him more business than he would ever obtain by doing unsatisfactory work.

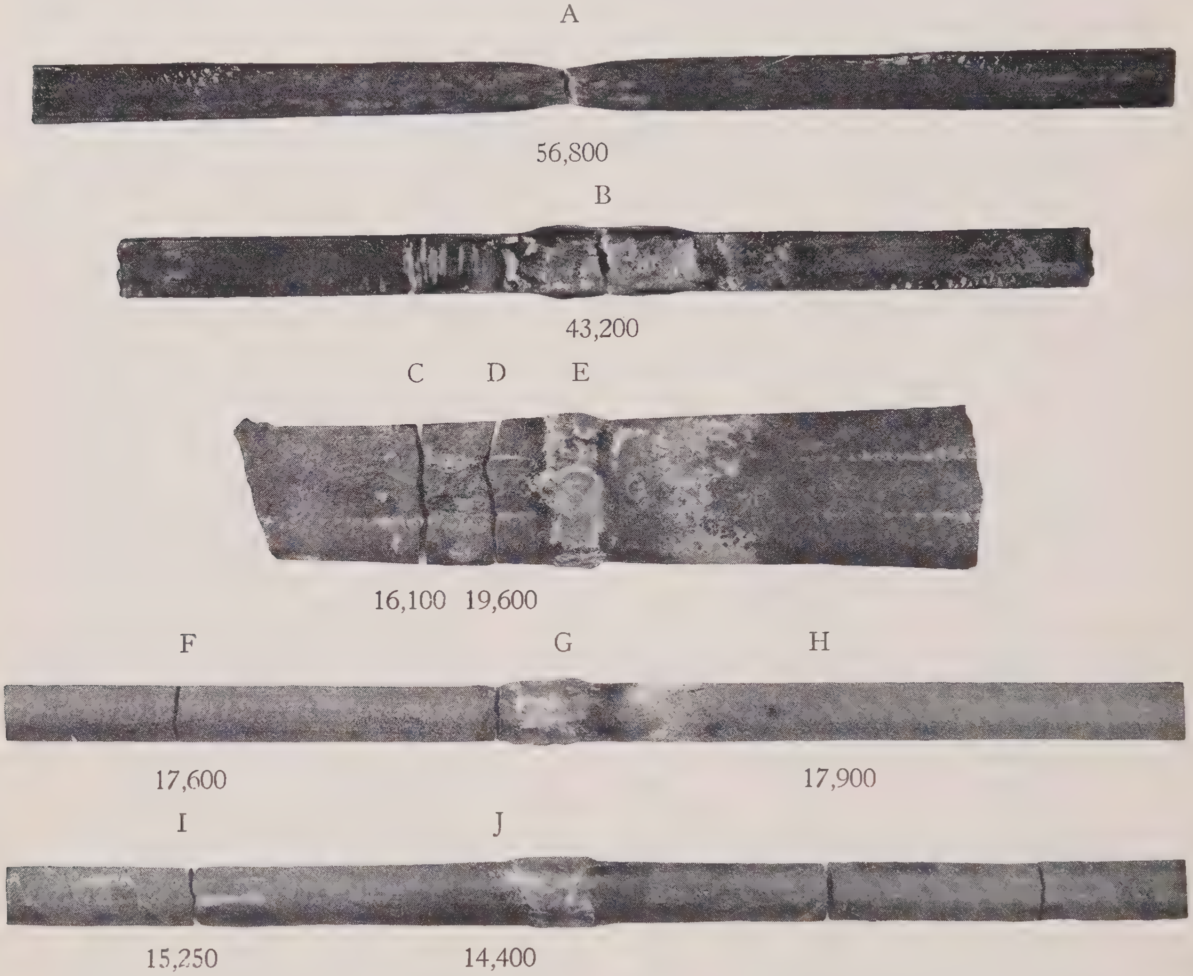


Figure 5—Test Bars Made by a Student. These Bars and Those Shown in Figure 6 Were Tested by the University of Minnesota.

It is, therefore, important that the shop owner, who is conscientious about the output of his shop, should take some steps to be sure that his welders do produce good welds. It has been found that some men who have been welding for years do not make as strong welds as those who have been properly trained in welding, but have had much less experience. The reason for this quite often is the fact that these welders have never actually tested any of their work. They proceed in the same general manner which they have used for many years, without any thought or knowledge that the welds which they are making perhaps are not as strong as they could be made. When new men are hired for shop work many men will claim to be welders who have had relatively little experience and are really not good welders.

A very excellent method of determining whether a welder is experienced or not is to request him to weld a test bar. This bar should be three-eighths of an inch in thickness, two inches wide and made of two pieces each six inches long. The material from which the bar is made should be a low carbon steel. These bars after being welded should be placed in a vise and bent over to an angle of 180-degrees, as shown in some of the illustrations. A bend of this kind will very quickly determine the ductility of the weld, although, of course, it will not determine its pulling strength. Most welding shops are not so located that they could have test bars pulled for tensile strength and the cost would be too great. Hence the test in the vise must usually suffice for the purpose.

In like manner, two pieces of cast iron may be selected and bronze welded, or fusion welded with cast iron, or two pieces of aluminum from an old scrap crank case. These tests will quickly show the welder any defects in the weld made, which perhaps he has never known of previously. Defective welds are usually caused by faulty procedure and a man cannot know the result of the method which he employs, unless he has had the experience of making welds and afterwards breaking them. In productive work, or when welding castings for customers, it is, of course, impossible to break the welds made thus sacrificing the jobs and for this reason many welders go on, even for years, without accurate knowledge of the kind of work they are doing.

An excellent illustration of the work of a student is indicated in Figure 5. A is a break in an ordinary bar of steel unwelded. This bar was three-quarters of an inch square. It broke, as indicated, when pulled in a Universal testing machine, at 56,800 pounds per square inch. B is a bar of the same steel, bronze welded, which broke in the testing machine at 43,200 pounds per square inch. This break indicates how a bronze weld should break, if the bronze is well applied, through the center of the weld and not by separating the bronze from the steel. In other words, bronze properly applied to steel has greater tenacity in the union between the bronze and the steel than the strength of the bronze itself.

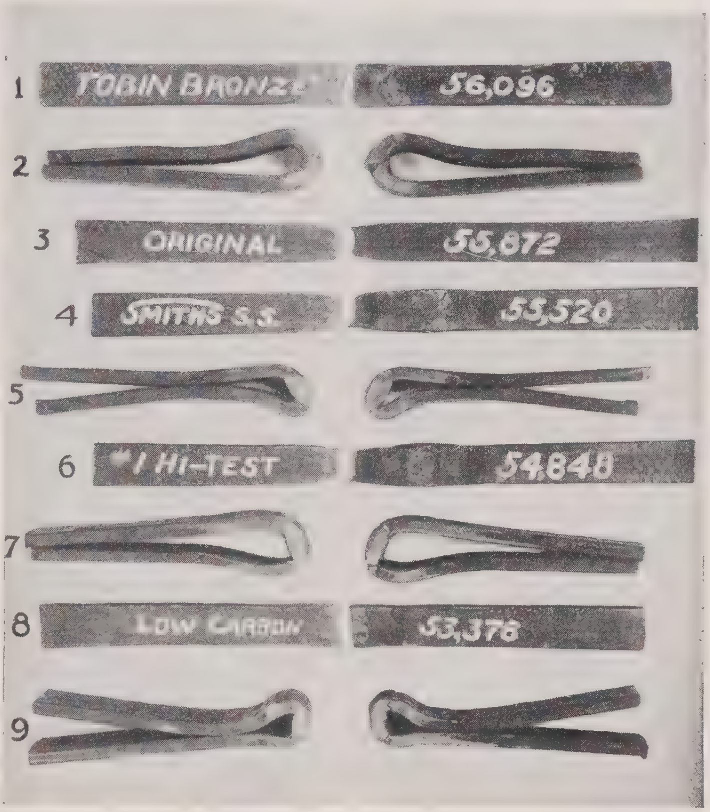


Figure 6—Test Bars Made by a More Experienced Welder.

The bronze weld E is made in a spoke broken out of a cast iron gear wheel. It was bronze welded in the usual manner and pulled in the testing machine for tensile strength. It will be noted that the spoke itself broke in two places, the break C occurring at a pull of 16,100 pounds per square inch and the break D at a pull of 19,600 pounds per square inch. The bronze weld did not break indicating that the bronze weld was stronger than the cast iron. The bronze welds G and J in the round rods were made in pieces of cast iron bushing stock which is soft grey iron, having a relatively low tensile strength. The breaks F and H occurred, as will be noted, well away from the bronze welds through the cast iron. F broke at 17,600 pounds and H at 17,900 pounds. The breaks I and J in the lower bar occurred at places in the cast iron rods where there were small defects in the metal, which were visible after the bar had been broken. I broke at 15,250 pounds and J at 14,400 pounds per square inch. It should be understood that all of these welds were made by a student. In the cast iron, however, all were stronger than the material welded.

In Figure 6 test bars, welded by a more skillful welder, are shown. The material used in making these test bars was five-sixteenths inch by one inch band iron. The pieces to be welded were cut six inches in length and bevelled to a double vee on one end. In all there were sixteen pieces, aside from the original bar, cut six inches in length, which permitted the welding of two welded samples with each of the four kinds of welding rods. The welding rods used, as shown in Figure 6, were Tobin Bronze, Smith's Special Steel, No. 1 High Test and low carbon welding rods. The low carbon rod conforms to the specifications, G No. 1A, of the American Welding Society. The No. 1 High Test Rods are the patented, carbon, manganese, silicon, steel welding rods, shown as No. 7, page 155, Lesson No. 10. The rods used for No. 4, Figure 6, are new rods which are made of nickel, chromium alloy steel.

Welds Nos. 1 and 2 were made by placing two of the test bars together with the bevelled ends abutting and selecting two more of these bars and placing these parallel with and close to the first two bars. The welds were then made with Tobin Bronze and are illustrated in Figure 6. Welding in this manner made available one test bar, which could be pulled in the testing machine and one bar which could be bent in a vise to 180-degrees, as shown. Both of the bars were welded under similar conditions, one immediately following the other. In Figure 6, the bent bars to the left are photographs of one side of each bent bar and to the right photographs of the opposite side of the same bar. The photograph was made by exposing the left hand side of the plate first, then turning the bent bars over on their opposite sides, moving them to the right hand side and exposing the right hand side of the plate.

The welds made with Tobin Bronze were good welds. Weld No. 1 broke at 56,096 pounds per square inch through the weld. The breaking strength of the original bar unwelded, shown at No. 3, was 55,872 pounds. The piece which was bronze welded, shown at No. 1, may have been a little stronger, or the heat treatment it received during bronze welding may have been beneficial. The bent bars, shown at Figure 2, show cracks under a bend of 180-degrees which is to be expected.

The bars shown at No. 4 and No. 5 were welded with special steel. Bar No. 4 was broken in the tensile test machine at 55,520 pounds. Bar No. 5 was bent to an angle of 180-degrees and it cracked, as indicated across the bar, adjacent the union of the weld metal and the bar steel. Bars Nos. 6 and 7 were welded with No. 1 High Test welding rods and No. 6 broke at 54,848 pounds. Bar No. 7, when bent, broke across the piece. The break again occurred adjacent the union between the weld metal and the bar. The reason for this is probably the fact that the weld metal had been reinforced slightly and was a little thicker than the original bar. It should be noted that both of these bars No. 4 and 6 broke outside of the weld, and both broke at a tensile strength slightly less than the breaking strain of the original bar.

Bars No. 8 and 9 were welded with low carbon steel rods of the specification G-No. 1A of the American Welding Society and bar No. 8 broke at 53,376 pounds, directly through the weld. It should be noted, however, in No. 9 that the 180-degree bend was made in this bar without any crack through the weld at all, showing that a low carbon welding rod produces a more ductile weld than the higher carbon rod used for bars No. 4 and 6, but also a weld having slightly less tensile strength.

These were rough and ready tests, as the bars were not all machined to exact dimensions and the exact carbon content of the original steel is unknown, but they serve to illustrate what can be done by the shop owner to prove that the welds which his men are making are good welds.

Job Sheet No. 13

Bronze Welding Sheet Steel

Job Sheet No. 13 proposes to give the student some experience in the bronze welding of steel. To do this work the student should procure a supply of small pieces of sheet steel approximately one-eighth inch in thickness, a tip assembly the size of a No. 2, a can of A-Mal-Gam No. 3, some one-eighth inch Tobin Bronze welding rods and the usual cylinder and regulator equipment.

Place two of the pieces of sheet steel across some fire bricks so that their edges are approximately one-thirty-second inch apart. This small space will permit the flux and the bronze to work down between the edges and give a strong joint.

The torch should now be lighted and the flame brought to play upon the pieces of steel. When the steel approaches a dull red heat, bring the end of the welding rod into the envelope of the flame for a moment to heat it and then stick the end of the welding rod into the can of flux where the heat of the rod will cause some of the flux to adhere to the end of the rod. The end of the rod should now be brought again into the envelope of the flame and the flux adhering to the rod allowed to melt from the rod and spread out over the edges of the steel. This process should be repeated until the steel is well coated with flux.

After the steel has been well fluxed, the steel should be "tinned" and the bronze applied in a manner similar to that described for the bronze welding of cast iron in Job Sheet No. 12.

The points emphasized in Job Sheet No. 12, apply equally well to the bronze welding of steel and the student should, therefore, keep them in mind.

When the pieces have been bronze welded together from one side, they should be turned over and similarly welded upon the other side. This develops a stronger joint between thin pieces of metal. When applying the bronze to the second side of the pieces, care must be taken, however, not to overheat and burn the bronze first applied.

After the pieces have cooled slowly in the air, the student should place them in a vise and break them apart by bending them through the weld. The welding of pieces together should continue until the student has remedied any defects noted when the pieces are broken apart.

Questions:

1. What is overhead?
2. Why does a welding shop need a cost system?
3. What is meant when it is said that a steel bar has a tensile strength of 55,000 pounds per square inch?
4. What are the items that must be included when figuring the price to be charged for a piece of work?
5. If a man in a welding shop starts on a job with an oxygen cylinder containing 1750 pounds pressure and finds upon completion of the job the cylinder contains only 875 pounds pressure, approximately how much acetylene and oxygen has he used on this job?

Lesson No. 14
Fusion Welding of Cast Iron
Cutting Cast Iron

BRONZE welding cast iron, malleable iron and steel were thoroughly discussed in Lessons Number 11 and 12. As stated at the beginning of Lesson No. 11, there are two general methods of welding cast iron, one being bronze welding and the other fusion welding. By fusion welding is meant the actual fusion, or melting of the cast iron, together with cast iron welding rods. This is the older method, but on account of the necessity for preheating the castings and allowing them to cool very slowly, bronze welding has to a large extent superseded this older method. For that reason bronze welding was discussed previously, in this course of instruction, because it was considered the more important process and one which the student should be thoroughly familiar with even before he took up the subject of cast iron welding. Most welders consider the welding of cast iron by the fusion process much easier than the welding of steel. In fact, cast iron is often said to be the easiest metal to weld.

As already stated in Lessons Number 11 and 12, expansion and contraction must be taken into account and slow cooling is especially important because of the change which takes place in the carbon of cast iron when rapidly cooled from a molten state. A complete discussion of the characteristics of cast iron will be found in Lesson No. 11 and in this same lesson the subject of preheating is fully covered. It is essential, therefore, in studying the fusion welding of cast iron that both Lessons 11 and 12 be thoroughly understood.

When cast iron is melted, a scum of oxide forms upon its surface which will prevent the flowing together of two puddles of molten iron until the film is broken up mechanically, by stirring the two puddles together with a welding rod, or chemically by dissolving it with flux. The melting point of the oxide is higher than the melting point of the cast iron itself, and for this reason it does not fuse or melt into the iron puddle. In welding cast iron it is, therefore, necessary to use a good cast iron flux.

It is also essential to use a good grade of cast iron welding rods. These are normally supplied in diameters of three-sixteenths, one-quarter, five-sixteenths, three-eighths and one-half inch and in lengths of from twelve to eighteen inches. They should conform to the specifications of the American Welding Society for cast iron rods as set forth in their bulletin No. 2. This specification gives an analysis as follows:

Carbon	3.00-3.50 per cent
Manganese	0.50-0.75 of 1 per cent
Phosphorus	0.50-0.70 of 1 per cent
Sulphur	0.10 of 1 per cent
Silicon	3.00-3.50 per cent

These rods may be obtained either round, square or hexagonal in shape. Silicon in cast iron assists in the precipitation of graphite as the weld cools, and for this reason good cast iron welding rods always contain a high percentage of silicon. The result is that less carbon remains in the combined form and a greater percentage is precipitated in the form of graphite flakes which make the weld soft.

Hard Spots in Cast Iron Welds

Hard spots in a cast iron weld, often complained of by machinists, finishing up a casting which has been welded, are caused by chilling portions of the weld by plunging the cold rod into the puddle of molten metal, or by allowing a part of the weld suddenly to become cool by removing the torch from it, or by failure to protect the hot weld from cool drafts or air. The result is a greater percentage of combined carbon and less of graphite; hence small parts of the casting are hard white iron instead of soft grey iron.

Hard spots may also be caused by the chilling effect of the metal surrounding the weld. The casting adjacent the weld must be kept hot so that there will be no chilling action along the border of the weld between the weld metal and the metal of the casting; otherwise, there may be a hard area along this boundary which will cause trouble in machining and finishing the surface of the casting. If proper care is taken, both in preheating, welding and subsequent cooling of the casting and if it is thoroughly protected during welding, there is no reason for having any part of the weld or the adjacent metal hard.

Shrinkage of Cast Iron

In cooling, grey iron shrinks about one-half as much as steel or white cast iron, but as the graphite is precipitated in the formation of grey iron, the crystals of the iron are pushed apart by the graphite to make room for itself and the result is a considerable expansion of the metal as it becomes solid from the molten state. After this expansion, as the metal continues to cool down, it contracts, but the net result is less total shrinkage. In making patterns for the three metals, the pattern maker will normally allow an expansion of one-eighth of an inch per foot for grey cast iron and one-quarter of an inch per foot for white cast iron and steel.

Soft Cast Iron Welds

The student will now appreciate that the degree of softness of the weld in cast iron is dependent largely upon the slowness with which it cools from the molten state and the uniformity of the temperature surrounding the metal. He will also appreciate that he cannot hope to produce uniform, soft welds in cast iron unless the casting is thoroughly protected during preheating, welding, and any subsequent heating operation to normalize or equalize strains which may have been set up. If castings are not properly protected, parts of the casting will cool with greater rapidity than other parts, with the result that certain portions of the weld may be hard and the metal may be strained by unequal expansion and contraction.

It is, therefore, very poor practice, for instance, to place a casting in a furnace, made permanently of steel and fire-brick and equipped with doors, for preheating. Such a furnace will, of course, preheat a casting very well, but when the casting is ready to be welded, it must be pulled out of the furnace into the cold air and the welding performed with the casting exposed to drafts and cold. It is true that the casting may be put back in the furnace and heated again, but this does not counteract the effect of the changing temperatures while the weld is being made.

Temporary Fire Brick Furnace Best

Common welding practice has, therefore, adopted the temporary fire-brick furnace, roughly built up of fire-brick laid around the casting and asbestos paper or sheet iron to cover the top. The reason for making a furnace like this is that a few of the brick, or a part of the asbestos cover may be pulled away to accomplish the weld, but the furnace remains, completely surrounding the casting during preheating, welding and any subsequent heating which may be given to the casting. The casting is never removed from the furnace, if the job is well done, until it is cold. In this manner the temperature is maintained at the right degree during the entire operation and the casting is entirely protected from sudden cold or drafts. If the preheating fuel used is charcoal, the heat of the burning fire is not enough to injure the casting, and a little more charcoal may be placed where a greater degree of heat is required. Furthermore, the casting may be left in the fire completely covered with the brick furnace, which may be wrapped tight with asbestos paper, and allowed to cool in the dying fire. If reheating is necessary more charcoal should be added to the fire and the temperature of the casting again raised to a dull red heat. The furnace may then be wrapped tight with asbestos paper and the fire allowed gradually to die out.

Melting Out the Vee

Many welders have formed the habit of melting out a crack or a vee in a casting. This is usually done to avoid the trouble of chipping the metal away along the crack. The welder will preheat the casting in the normal way and with the torch and the welding rod melt a short portion of the metal adjacent the crack and then scrape it out with the rod. He will continue this until he has a rough opening along the crack where the weld is to be accomplished. This is not good practice and should not be done under ordinary circumstances. It is unquestionably a cheaper way to vee out a crack in an iron casting, but the result will not be as satisfactory from a welding standpoint as a crack which has been chipped out either by hand or with a compressed air chipping hammer.

The reason for chipping, or veeing, a casting prior to welding it is to enable the welder to fuse the bottom edges of the crack first and then build up the cast iron until the entire section of the vee has been filled with molten metal thoroughly fused to the veed edges of the casting. When this is done, the welder can control the heat to better advantage and avoid suddenly chilling the edges of the metal or parts of the casting. When the crack is melted and scraped out with a rod, as just described, there is much greater opportunity for inequality in heating or cooling the metal. Chilled portions of the metal may occur resulting in hard spots.

Methods for the Fusion Welding of Cast Iron

There are three principal methods used for the fusion welding of cast iron. The first of these methods consists in melting a puddle, allowing it to solidify and melting a second puddle just ahead of the first puddle. The two puddles are made to overlap and the rear end of the second puddle is fused into the forward end of the first puddle. These consecutive puddles may progress along a seam and the method produces a very good weld. The second method is called the ripple welding of cast iron and is made by fusing one puddle after the other continuously. Only the rear end of the preceding puddle is allowed to solidify and the forward end kept in a molten condition, and this method continued along the seam. The result is a ripple weld which looks very much like a ripple weld in steel, but the ripples are not as clearly defined.

Ripple welding of cast iron is used to a greater extent by good cast iron welders than the first method described. The finished product has a smoother, more uniform surface than that resulting from the use of the first method, but not as smooth as that resulting from the following method. This third method is usually called smooth welding and consists merely in remelting the surface of the weld and finishing it smooth by the manipulation of the torch and the addition of more of the welding rod. One of the difficulties which a beginner in cast iron welding often encounters is proper control of the metal at the edge of the casting, or in building up a lug, or in the vertical welding of cast iron. Cast iron when molten, if heated sufficiently, becomes quite liquid and will run away without warning if the heat is not withdrawn momentarily to allow the metal to cool to a more solid state. Therefore, in building up a lug upon a casting, or building out a square edge, it is necessary to so hold the torch and remove it from time to time that the metal will solidify just at the right moment. A little practice will soon indicate just what is required, and a man skilled in the welding of other metals will have no difficulty. A more detailed description of these three methods of welding seems hardly necessary at this stage in the course in welding. The welder by this time has learned to manipulate both torch and rod so that he can skillfully handle cast iron just as well as steel or bronze.

Preheating a Heavy Casting

It is now assumed that the student has had enough practice in the manipulation of the torch to be able to make a satisfactory weld in cast iron and that his principal problem will be the manner in which castings are preheated and welded. Each casting represents a problem in itself and in similar castings breaks located at different points present entirely different problems. With all castings it is essential to plan the job to the finish before starting it and to take into consideration the effect of the heat where applied and whether or not the result would be more satisfactory if heat were placed in a different location or in a different degree. In other words, the welder must think out the entire job, before beginning it, if he is to be successful.

Sometime ago one of the French publications presented an example in welding which was so instructive that it was translated into English and published in the Acetylene and Welding Journal of London, England. The sketches are reproduced here to illustrate to the student the necessity for giving very careful consideration to the effect of heat upon the casting before proceeding with the job. The job in question was a press frame, weighing about five tons, and is illustrated in Figure 1. The break was in the upper part of the frame, A-B, and the crack occurred through the section of the casting surrounding the eight inch hole where the metal was five inches in thickness. The length of the crack was about eighteen inches. The casting, for a considerable period of time, was not welded, because of its weight and mass and the fact that it presented some unusual problems. Before the job was done, it was considered by several good welders and various theories were set forth as to the proper method for welding this job.

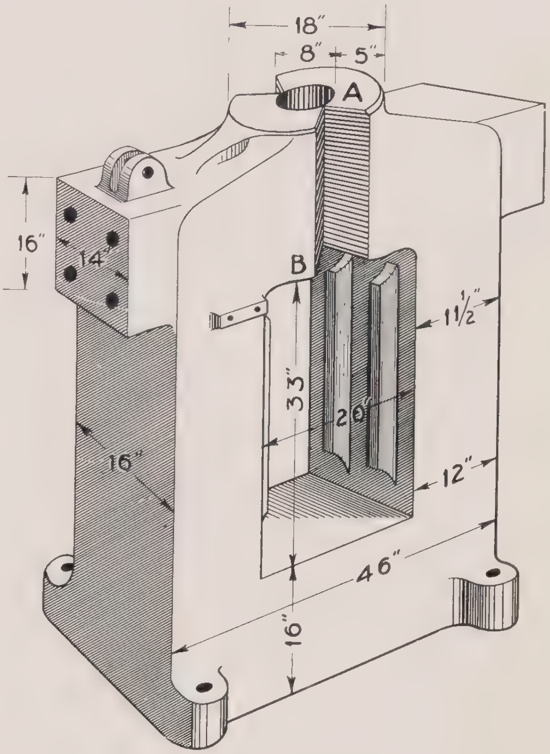


Figure 1—Sketch Showing a Press Frame Weighing Five Tons, Which Presented Some Difficult Problems to the Welder, Who Finally Made a Success of the Job. This Press was First Illustrated in a French Publication and Subsequently Described in the Acetylene and Welding Journal of London, England. The Veed Out Break is shown at the Top of the Casting at A-B and on the Opposite Side of the Casting.

The problem is just as interesting today as it was at that time, because other castings present similar conditions and must be handled in a generally similar manner. Furthermore, it illustrates forcibly the necessity for giving very careful consideration to preheating before attempting a job of considerable size. In the first place, the crack was veed out on each side, as shown at A-B, and the opposite wall was veed out in similar manner. Chipping was done with an air chipper and the angle of the vee was approximately ninety degrees.

Three methods of procedure were thoroughly discussed and the anticipated results of each method were given consideration before the job was started. In order to show these to best advantage, Figures 2, 3, and 4 have been drawn and are cross-sections through the center of the casting. In other words, in each of these figures the casting has been shown as if it were cut in half.

The first method considered was the heating of the casting, as shown in Figure 2, adjacent the portion to be welded, X-Y. The idea was that if the casting were heated along this area it would expand the two bevelled sections and they would crowd towards each other as indicated by the arrows. When cooling took place, it could only be expected that the contraction of this area of the metal together with the additional metal of the weld, would cause a very severe strain which might subsequently result in a crack and consequent failure of the weld. If it did not crack during cooling, it might set up strains in the metal which would ultimately result in cracks if an unusually heavy load were applied to the casting. This method, illustrated in Figure 2, was given no further consideration and was abandoned.

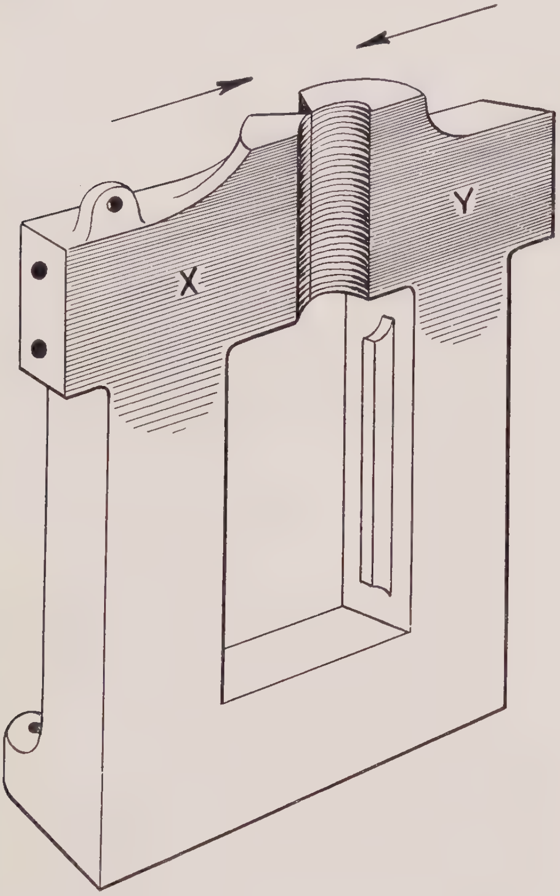


Figure 2—Sketch Showing a Suggested Method of Preheating Which was not Based on Sound Principles and Could not be Expected to Produce a Successful Weld. This is a Cross-Section Through the Center of the Casting, as if the Casting had been Cut in Half.

Figure 3 illustrates the second method discussed, consisting of heating the lower part of the casting, shown by the shaded area, and thus expanding the upper portion before beginning to weld. This is the usual method of handling such a job and for many castings would be entirely satisfactory. In this casting, however, the great mass of the iron, and the difficulty of handling a casting weighing five tons, made this particular casting an exception to the general rule. The considerable length of the crack makes it obvious that if the casting were preheated, as shown in Figure 3, placed on its side and the weld started at B, Figure 1, and continued to A, the portion of the weld at B would cool long before the welding reached the point A. This would result in internal strains and a crowding of the metal as the weld proceeded toward A, which could not be compensated.

The crowding would be the same as that which would occur if a weld were made between two long pieces of steel plate and the plates were not separated at the far end to allow for expansion as the weld progressed. The student will remember that this action of the steel plate was described on page 90 of Lesson No. 6 where plates being welded together were always spread at the far edge two and one-half per cent of the length of the seam. This is one of the important principles always considered in welding seams of any length between two pieces of plate. It is obvious,

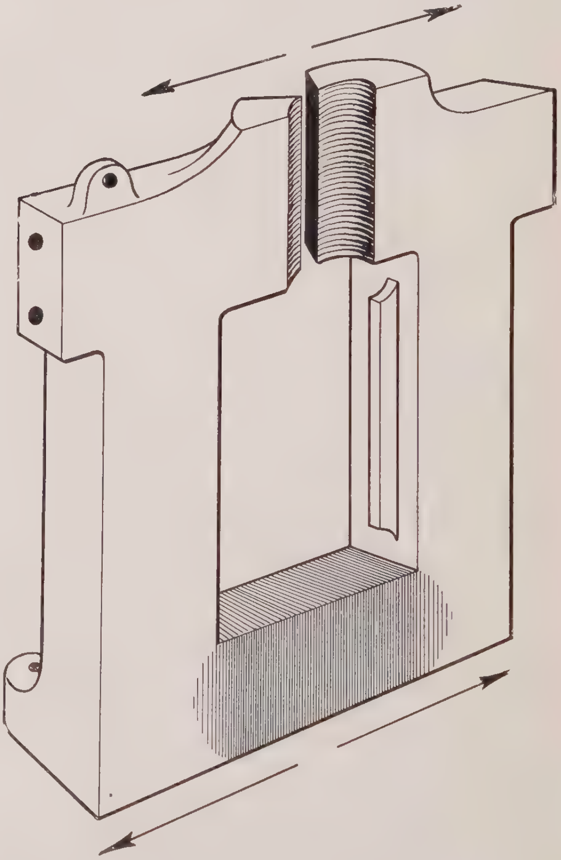


Figure 3—Sketch Showing a Second Method Suggested for Preheating the Casting, Which was also Abandoned, Because it was Believed that Successful Results Could not be Produced in This Manner.

therefore, that if the casting were heated, as shown in Figure 3, and welding begun at the point B, difficulties would be encountered before the weld was completed. It would then be necessary to tear down the temporary brick furnace, turn the casting over with a crane and weld the other side of the broken section in similar manner, where even more complicated strains would be set up.

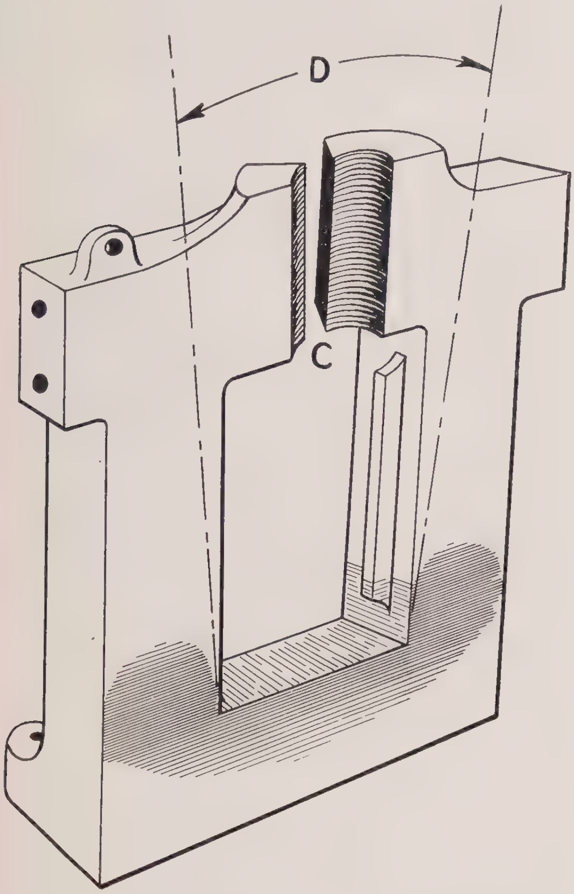


Figure 4—Sketch Illustrating the Final Method of Preheating Which was Successful. The Casting was Expanded as Shown at C-D, and two Welders Made the Weld, One Working from Each Side of the Casting with the Casting in an Upright Position. Preheating was Accomplished with a Temporary Fire-Brick Furnace, Built Around the Base of the Casting to Confine the Heat as Indicated by the Shaded Area.

For this reason the second method, illustrated in Figure 3, was abandoned and consideration given to expanding the opening more at the top than at the bottom. This is clearly indicated in Figure 4 and this was the method finally decided upon to accomplish the job. If the casting were heated only near the base, as shown in Figure 3, the expansion would be horizontal in opposing directions, as shown by the arrows. If, however, a portion of the casting at the bottom remains cool and an area were heated above the bottom of the casting, as shown by the shaded lines in Figure 4, a hinge action is the result and the upper portion of the casting towards B would be spread more than the lower portion of the break at C. The job was finally accomplished as follows:

The casting was set on its base on the floor of the shop in an upright position, as shown in Figure 1. The lower portion of the casting was bricked around above the floor level to prevent the fire from getting down too low towards the base and a temporary furnace built around it to confine the heat largely to the lower portion. Charcoal was used as a fuel, and the casting heated and expanded, as shown in Figure 4. Carbon plates were placed under the casting at B, Figure 1, to form a support for the metal and both welds were made simultaneously by two welders, one working from one side and the other from the opposite side. Both men began at the lower portion of the vee just over the carbon plates and welded vertically upward until the job was completed. The result was entirely successful and the casting served its purpose for a number of years afterwards. These illustrations show how a simple principle, like that previously described in Lesson No. 6, and for the convenience of the welder again shown in Figure 5, of this lesson, can be applied to a casting in the same manner in which it is applied to the long seam between steel plates.

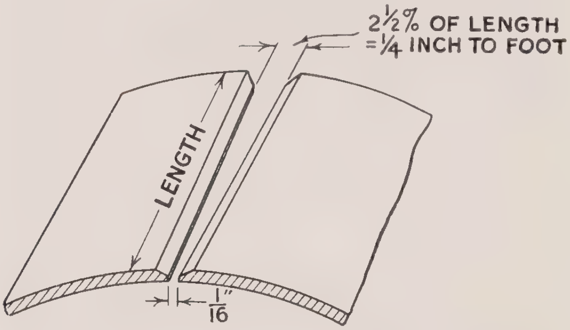


Figure 5—Sketch Showing the Principle Referred to, Described on Page 90, Lesson No. 6. The Near End of the Seam is Separated One-Sixteenth of an Inch and the Far End Two and One-Half Per Cent of the Length of the Seam. As the Weld Progresses Along the Seam, the Far Edges are Drawn Together Until They Just Meet as the Weld is Completed.

Alignment of Broken Parts

A very important part of the preparation of a casting for welding is the method of chipping the bevelled edges so that portions of the original break are left without injury and the two parts may be fitted together and will be in true alignment. Sometimes these portions, like the lug shown at B in Figure 6, are so small, or the break may be such that it would be extremely difficult to fit the part back into position so that it would line up as required after welding. For this reason a templet or bracket, shown by the letters A, B and C, in Figure 6, will be found very convenient for this purpose and will result in excellent alignment when the weld has been made.

In Figure 6 the lug, D-C, was broken from a casting. This lug was the weakest part of these castings and breaks very often occurred at D as indicated. The bent bar A, B, and C, securely held the lug in position during welding and at the same time acted as a templet to place the lug, D-C, in its correct position with relation to the rest of the casting. Both the lug and the casting were veed out to an angle of approximately 90-degrees as shown at D, and the weld made entirely from the upper surface with the casting in a horizontal position, as shown in Figure 6. This sketch has been made to illustrate an instance in which a bracket of this kind is essential.

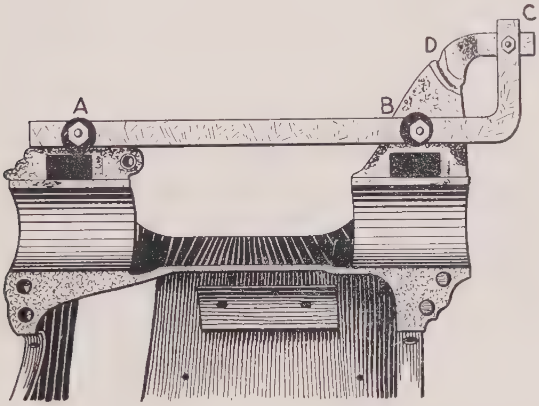


Figure 6—Sketch Showing a Bracket A, B, C Made to Hold a Lug D, C in Place, While Being Welded. Such Brackets are a Great Convenience to the Welder and Can be Quickly and Easily Made.

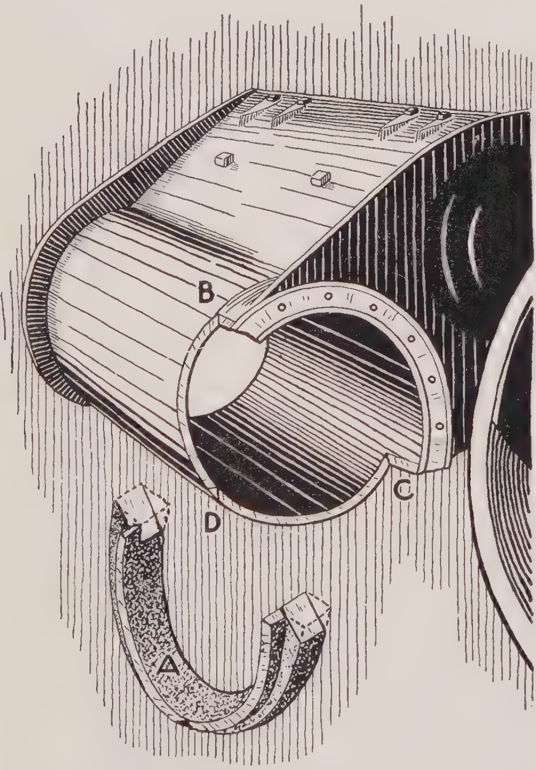


Figure 7—A Bad Break in a Locomotive Cylinder Casting. In Order to Save this Casting, It was Necessary to Cast a New Piece Shown at A, and Weld It Into Position in the Cylinder Casting.

There are many other similar cases and the welder must often use his ingenuity in devising similar brackets to hold the part to be welded correctly. Expansion and contraction are so slight, in the welding of a lug as small as this one, that it is not necessary to make any provision for either. The lug is held securely in place at C by the bar and will adjust itself along the line of the weld without difficulty. Of course, if the break were larger, or the section of the metal heavier, other arrangements would be necessary.

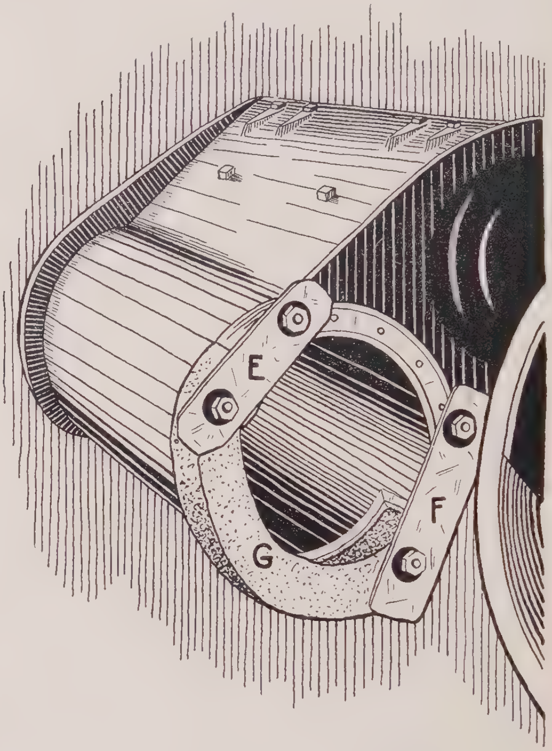


Figure 8—The New Cast Piece G Has been Fitted Into Place and is Held Securely in Position by the Plates E and F Bolted to the Cylinder and to the Piece Inserted.

Welding a Locomotive Cylinder Casting

An instance of cast iron welding, requiring considerable ingenuity on the part of the welder is illustrated in Figures 7, 8, 9 and 10. These illustrations are sketches made from an actual job accomplished as indicated.

In Figure 7 a bad break in the rear end of the cylinder casting is shown. The whole lower portion of the flange and a part of the casting was broken away, as indicated by the letters B-C. Because the pieces were lost, it was necessary to cast a new flanged portion which would fit the space after the casting had been cut away and trimmed to solid metal. Before the pattern for the casting A was made, it was, of course, necessary for the welder to decide just how the job was to be done, because the edges of the cylinder casting and the new flange were to be bevelled and the bevel must open in the direction from which the weld is to be made.

It is obvious that it would be a particularly difficult thing to weld underneath the casting from B to C. It would not, however, be difficult to weld from the outside of the casting from D to B. The welder in this case decided that he would weld from the inside of the cylinder from D to C; for this reason the bevel was made with the wide part facing upward. The weld, D-C, therefore, was a horizontal one from the inside of the cylinder, but if it had been continued on the inside of the cylinder from D to B, overhead welding would have been necessary at B and vertical welding part way up the side of the circumference of the cylinder. It was, therefore, decided to bevel the portion of the cylinder from B to D from the outside, and to make this weld from the outside.

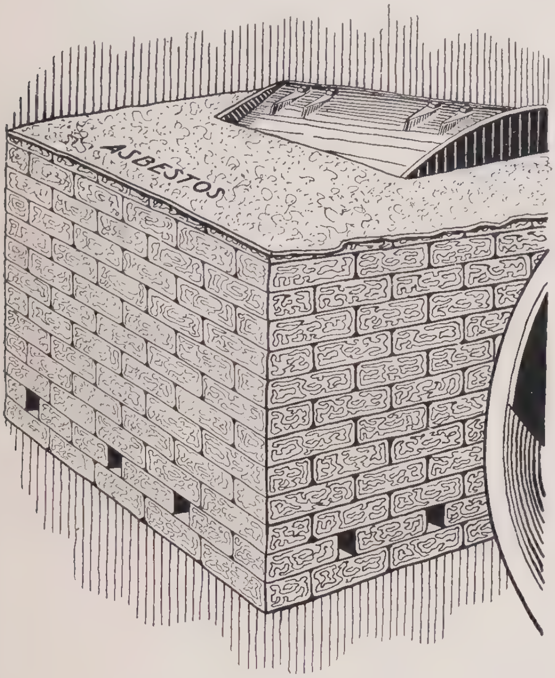


Figure 9—The Cylinder Casting, After Being Prepared for Welding, Was Entirely Surrounded by a Rough Fire-Brick Preheating Furnace and Covered Over the Top with a Sheet of Asbestos. Such a Furnace Produces Excellent Results, because It Allows the Welder to Tear Down a Portion of It Wherever May be Necessary to get at the Part to be Welded.

The pattern for the piece A was made and the piece was cast with the edges bevelled and the bevels were chipped along the edge of the casting D-C, Figure 7. The piece A was then fitted into position, as shown at G, Figure 8, and securely held by two pieces of flat plate E and F, bolted to the piece G and also to the cylinder flange. The cylinder was then ready to be preheated which was accomplished by building a rough fire-brick furnace around the cylinder, as shown in Figure 9. An asbestos cover was placed over the top of the furnace, after it had been partly filled with charcoal and the charcoal ignited with the torch. Holes were left at the bottom of the furnace to admit air, and there was enough space around the top of the asbestos cover to allow the gases to escape.

The great value of a rough brick furnace of this kind lies in the fact that a piece of the asbestos paper may be torn away and several bricks removed in order to get at the end of the casting, where the welding is to be done, without tearing down the rest of the furnace. At the same time the charcoal fire continues to burn and maintains the temperature as warm as possible around the casting.

After the welder had pulled away bricks enough so that he could get at the inside of the casting, the weld from G to F was completed from the inside. When this was done, the end of the furnace was covered with more asbestos paper and a few bricks torn away to permit welding to be carried on from B to D, Figure 7. The result was an excellent fusion weld along the entire seam. More charcoal was then added and the fire burned up for a short time; the entire furnace and the top of the casting were then entirely covered with asbestos paper and allowed to cool down very slowly.

The finished job is shown in Figure 10. The interior surface of the weld was made reasonably smooth as the weld progressed and ground where necessary with a portable grinding wheel. The flange was afterwards machined and the cylinder assembled. In this manner a repair was made which saved a very expensive casting otherwise only of scrap value.

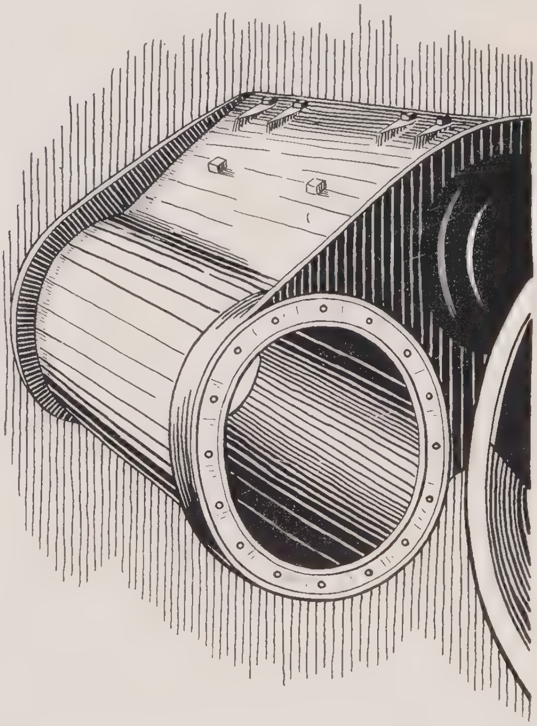


Figure 10—The Completed Repair. In this Manner a Valuable Casting was Saved which Would Otherwise have Had only Scrap Value. The Labor of Removing Such a Casting from a Locomotive and Replacing it with a New One is in Itself Expensive.

One of the principal objects in showing this series of illustrations is to impress upon the student the necessity for planning the job from the beginning to completion, before it is started. If each step in the process of welding, the preparation, the alignment of the part being welded in place and the preheating is carefully planned, in such manner that the weld can be made in the most convenient way and with due thought given to the effect of expansion as the weld progresses, a job of this kind can be done very successfully.

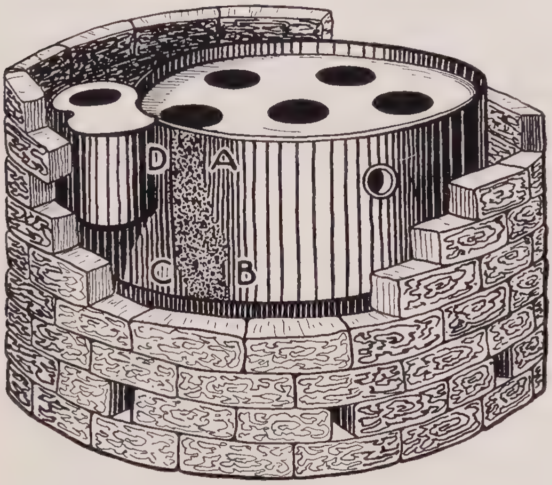


Figure 11—Sketch Showing a Circular Heater Section Surrounded by a Circular Preheating Furnace. The Casting was Set on Its End and the Welds A-B and C-D made Vertically, Beginning at the Points B and C Respectively, and Welding Towards the Points A and D. Charcoal was Used for Preheating and the Furnace was Covered with a Sheet of Asbestos Paper.

Welding Cast Iron Boiler Sections

This subject is a particularly interesting one, because so many welding shops have great difficulty in welding boiler sections and only a few shops, where a specialty is made of this work, are entirely successful. The principal reason for the success of those shops which have specialized in boiler sections is the fact that their men have learned the secret of preheating boiler sections; and they follow, strictly, a certain routine which is about to be described. Cast iron boiler sections are made in various shapes and of various designs, but they are all intricate castings having comparatively thin walls and are hollow to permit the circulation of the water in the boiler. When heat is applied to such castings, it must be evenly distributed over the whole casting, or there is almost certain to be in the expansion of the metal an inequality which will cause the thin cast iron wall to break.

The first requirement for successful welding, therefore, lies in preheating the entire casting. Partial preheating is not enough, because the casting is so intricate and the walls are so thin, that it is impossible in most cases partially to preheat the casting and prevent unequal expansion. This usually results in cracks in the cast iron. Figures 11 and 13 both illustrate boiler sections which have been entirely enclosed in fire-brick furnaces. Figure 12, on the other hand, shows a boiler section with only one-half of the section enclosed in the furnace as many welders attempt to do this work, a method which usually ends in failure. Furthermore, in Figure 12, insufficient space has been allowed underneath the boiler section for a good charcoal fire, with the result that an even fire under the heater would be extremely difficult to maintain.

In order that the entire process may be understood, each figure is described separately and the reasons for accomplishing the work in the manner shown are given. Figure 11 illustrates an old type of boiler section, which was successfully welded in a circular fire-brick furnace, as illustrated. The break occurred in the form of two cracks, A-B, and C-D. Many welders would have placed this casting on its side with the break upward, but if the student will consider this method for a few moments, he will realize that equality in heating under these conditions would be very difficult to attain. The holes through the boiler section constitute ports or openings where the heat of the preheating fire must rise evenly to preheat the casting; for this reason the casting was set, as shown in Figure 11, on end, and the weld A-B, C-D, made in a vertical position.

This was more difficult for the welder, but the important feature in welding boiler sections is preheating which takes precedence over any other consideration. The broken piece between the two cracks was not completely broken out, and as the thickness of the wall of the section was very thin, not more than three-sixteenths of an inch, the cracks were not veed prior to welding. The boiler section was set up on fire-brick about six inches above the floor and the circular furnace completely built around it. Charcoal was used as a preheating fuel, and the casting very slowly heated until a dull red temperature was reached.

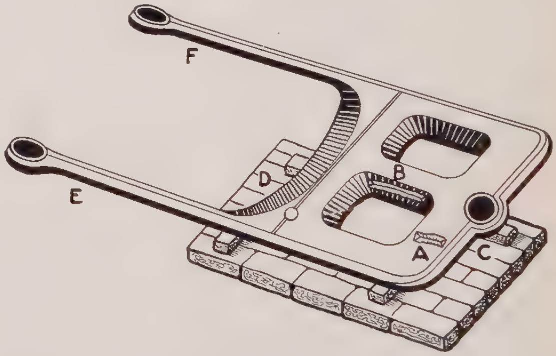


Figure 12—This Sketch Has been Made to Illustrate the Wrong Way to Heat a Cast Iron Boiler Section. If the Furnace Had Been Completed Around the Base Section, Only a Portion of the Boiler Section Would have been Included in the Furnace and Part would have Projected into the Cold Air. Partial Preheating of Boiler Sections is not Usually Successful.

During preheating there was, of course, an asbestos sheet placed over the entire furnace and, when welding, only a few bricks were pulled away adjacent to the break, A. B. C. D, to enable the welder to operate through the hole. When the casting is thin, as in this instance, the metal along the crack may be raked out with the welding rod. While this practice has been condemned in a previous paragraph, it may be used in the case of boiler sections having very thin walls. If the section has a heavier wall, it is better practice to chip the vee, as heretofore described. In the case of a vertical weld, it is always best to start at the bottom and weld upward toward the top.

In Figure 11, the weld was started at B, after the casting had been thoroughly preheated, and continued upward toward A. About two inches of the crack at B was melted with the welding torch and the rod used to rake out a small amount of metal along the crack. It is not good practice to rake out too much metal, because the welder will have more trouble in making a vertical weld if the veed out portion is too wide. The first two inches thus raked out were welded and then two more inches and so on until the weld reached the top of the casting at A; in a similar manner the crack from C to D was welded. After the weld was completed a little more charcoal was added to the fire and for about twenty-five minutes the casting reheated until a very dull red in color. The entire furnace was then completely covered up and the casting allowed to cool with the dying fire.

In Figure 12 a boiler section is illustrated as welders often attempt to weld these castings, that is, by building a preheating furnace around only those parts where the cracks occur. In this section there was a crack at A and another one at B. As indicated in Figure 12, the welder attempted to build a preheating furnace around only part of the casting. If the walls of the furnace were built up in this manner with one-half of the casting sticking out of the furnace, and the two legs E and F, projecting beyond the walls, the portion of the casting A, B, C, D, lying within the furnace would be heated to a dull red, but that portion extending beyond the walls would be cold. The result would be strains in the metal in the portion projecting from the furnace and the thin cast iron walls of the casting would be likely to crack somewhere in this vicinity. Partial preheating of boiler sections is likely to result in trouble and should be avoided.

In Figure 13, a large, heavy boiler section is shown, and the method of procedure in welding a casting of this kind should be as follows: A fire-brick floor should be laid on the floor of the welding shop, a little larger than the entire casting, when the casting is laid flat, as shown in Figure 13. The crack should be chipped out in a heavy section of this kind, as indicated. The casting should be supported at a number of places with fire-bricks and shimmed up with wedges so that it will not sag or warp. The walls of the furnace may now be built up by laying the fire-brick roughly around the casting. One or two small I beams, or angle iron bars should be laid across the walls to act as a support for the asbestos paper top.

About a bushel or more of charcoal should be lighted with the torch and shoveled underneath the casting. A second bushel or so of charcoal should be spread around the casting between the brick walls of the furnace and the casting, and it should be lighted at several places with the welding torch. When the fire is burning evenly all around the furnace, the asbestos sheets should be placed over the top of the furnace and a few holes punched in them to allow the gases to escape. About an hour later, additional charcoal should be added to the fire, depending somewhat upon the size of the furnace, probably about two bushels. After four or five hours of slow heating the casting will be a blood red in color, as shown at No. 2, page 109, Lesson No. 7. The corresponding temperature for this color is given as 1050 degrees Fahrenheit. The casting is now ready to be welded.

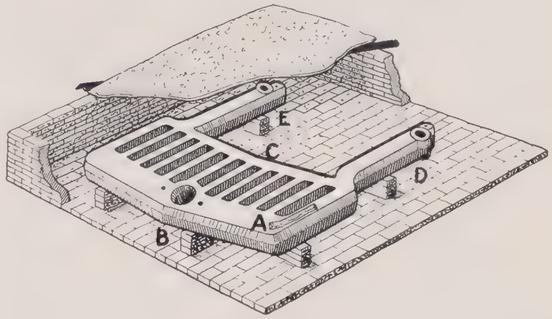


Figure 13—This Sketch Shows the Right Method for Completely Preheating a Boiler Section. The Section is High Enough Above the Brick Floor to Allow the Fire to Burn Under It, and the Entire Section has been Surrounded by a Brick Wall. Several Small I Beams or Angle Irons are Placed Across the Top of the Furnace and the Entire Furnace Covered with Asbestos Sheets. This Method is a Most Successful Method for Accomplishing these Welds.

As little of the asbestos paper top as possible should be pulled away and the crack A welded. If the cracks are located in the casting somewhere near the line, B-C, so that a welder has to reach over the furnace to accomplish the work, it is good practice to use one or two extensions upon the torch to make it long enough to reach the crack without subjecting the welder to too much heat. Asbestos gloves are often essential for doing this kind of work and sometimes an asbestos shield placed around the torch to protect the welder's hands from the heat will be found necessary.

When the crack A is the only one in the casting, as shown in Figure 13, as soon as it is welded, more charcoal should be added to the fire and the casting again heated for about one-half hour. The furnace should then be packed tight with asbestos paper and the casting allowed to cool with the dying fire. If there is a crack in the edge of the section instead of on the upper surface, welding should begin at the bottom of the crack and be continued upward. If the crack extends from one of the central openings in the casting part way into the solid portion of the metal, the weld should begin at the inner end of the crack and continue outward to the opening.

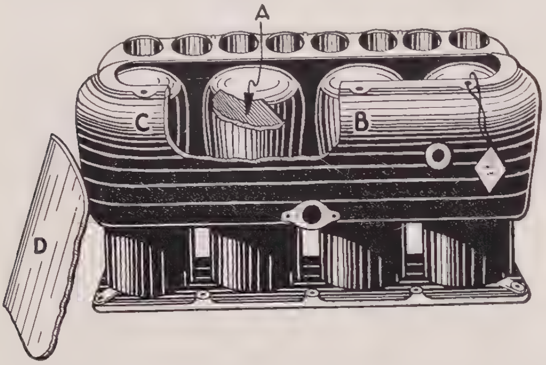


Figure 14—Sketch Showing a Cast Iron Cylinder Block of an Old Type Where the Wall of the Cylinder was Broken Away. It was Necessary to Cut the Piece D Out of the Water Jacket and Reweld it in Place After the Break A had been Completely Welded. Note the Metal Identification Tag at the Right of the Illustration. These Tags Were Described in Lesson No. 13.

If there is a crack on each side of the casting, it is necessary to weld up the first crack and then turn the casting over. This can be accomplished quickly if the casting is handled as it should be. When one side has been completed, the asbestos paper cover over the furnace should be removed and two pieces of pipe about six feet long inserted in the holes D and E. One man on each piece of pipe can quickly turn the casting upward on its edge B. Another piece of pipe is inserted in the hole B and the casting moved to the opposite side of the furnace. The pipes through the holes D and E are then reversed and the casting lowered in the furnace on its opposite side.

It is necessary to build up the supports for the casting again as was previously done. After the casting has been thoroughly supported, the charcoal fire is built in similar manner and the casting heated slowly until it has reached a faint red in color. During this heating the furnace is, of course, covered with the asbestos paper covers and when the casting is sufficiently hot, the break on the opposite side is welded in a manner similar to that already described. After welding the second side of the casting, a little more charcoal is added to the fire and the casting evenly heated for about half an hour. The casting is then allowed to cool in the dying fire.

When stone cold, and not until then, the casting may be removed from the furnace. During the time that the casting is being turned over in the fire, it is essential that all the doors of the welding shop and any windows that may be open, be closed to prevent cold drafts of air from sweeping in against the hot casting. If this is not done, a cold draft will crack a casting of this kind very quickly.

The welder will appreciate that this is quite an elaborate method for welding cast iron heater sections, but if it is followed through carefully and the work skilfully done, cast iron heater sections may be welded without cracking them or causing them to warp out of shape. If, however, such care is not taken, the result is almost always a failure and the conclusion of the welder that such castings cannot be successfully welded usually follows.

Welding an Automobile Cylinder Block

The fusion welding of a cast iron automobile cylinder block does not differ from the welding of any other casting of a complicated nature. Figure 14 has been drawn to show how a break in the cylinder underneath the water jacket of an old type of cylinder block can be welded by cutting out a piece of the water jacket, D, so that the welder can get at the inside break, A. This is a sketch of an actual job accomplished some years ago, but serves to illustrate the method.

Of course, a cylinder block must be preheated entirely. It is set on level supports and completely surrounded by a rough fire-brick wall. The charcoal fire is placed underneath the block, as well as around it, and preheats it evenly throughout. In the instance shown in Figure 14, the piece D was cut out of the water jacket, B-C, and the piece A fitted into position before the casting was placed in the fire-brick furnace.

When the casting had been carefully preheated, the piece A was welded in position; in the meantime the piece D had been preheated in the furnace with the casting. When the piece A was completely welded through a hole in the asbestos cover of the furnace, the piece D was inserted in its proper position in the wall B-C, without removing any more of the asbestos paper top and the brick side wall than necessary, and while held with tongs was tack welded. In welding the patch D in place, the weld should start at the center of the lower seam and be carried to the corner at C, then beginning again at the center, welded to the corner at B. These corners were left round in order to avoid square corners which are always objectionable. Finally the weld should be made at C, from the corner out to the edge, and then at B from the corner out to the edge. In this way the additional expansion of the fusion weld is compensated for, as much as possible, despite the fact that the casting has already been preheated to a blood red heat.

When all welding was completed, the casting was reheated, as formerly described, and allowed to cool with the dying fire, after the furnace had been completely covered up. The metal tag to identify castings while being preheated is shown to the right of Figure 14. This tag was fully described in Lesson No. 13, and is an excellent means of identification.

Welding Stove Parts

Figure 15 illustrates a very common job which is often brought to the job shop for repair, that of a broken stove leg. It is true that the cost of a stove leg is not much, and that welding in many cases would not pay, if a new part were available, but in many instances it is difficult to secure a new leg and welding is necessary to remedy the difficulty as promptly as possible. Stove parts, such as the leg illustrated in Figure 15, do not present any particular difficulty in welding, but even this part should be preheated when a fusion weld is to be made. If, however, the stove part is a frame, it must then be very carefully preheated in order to prevent unequal expansion and cracking of the casting. The principles are identically the same as those heretofore described for other castings.

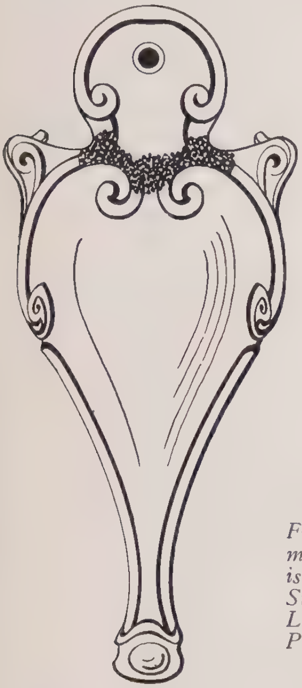


Figure 15—A Very Common Job in a Welding Shop is the Repair of Broken Stove Parts. Broken Stove Legs are Easily Welded and Present no Particular Problems.

Welders Often Use Wrong Methods for Preheating

In Figure 16 a heavy die press frame is illustrated as the job was actually welded. It will be noted that the base B is very heavy and the top D is also heavy. The sides were lighter in section and were held against strain by the rods shown. In this instance the welder decided that a good method to weld the casting was the least tedious one from a welding point of view, and this method is illustrated in Figure 16. He built a preheating furnace A, which acted as a support for the frame. He also built a small pier B, to support the other end of the frame. The break shown in the lower side section of the frame was chipped out in the usual manner to a vee and all the welding done from the upper side.

He preheated the casting along the line of weld by having a fire in the supporting furnace A, directly underneath the casting, but he did not surround the upper part of the casting with the walls of the furnace, or attempt to confine the heat. He also made no provision to heat the other side wall of the frame at E. The greater part of the casting was, therefore, cold and the only section which became at all hot was that immediately adjacent to the weld.

A little thought in this connection will show what happened in this case. Preheating the casting at A, of course, caused the lower side wall of the frame to expand, which produced a bending effect at E. This wall of the casting, however, was far too heavy to spring without causing a strain in the metal at the point E.

If the welder had given a little more consideration to this job, he would have turned the casting flat on its base C and top D. He would have veed the casting from the outside at A, so that the weld could have been made entirely from this side, and he would have supported the top D in good alignment with the base C. He would then have built a furnace around the side wall of the casting at A, and another furnace around the opposite side wall at E. He would have preheated both side walls, thus expanding them equally and avoiding the strain which would otherwise occur at E. The weld in the side wall A would then be made vertically. This method would have avoided the hinge effect at E, caused by the method used in Figure 16, and would have successfully accomplished the job.

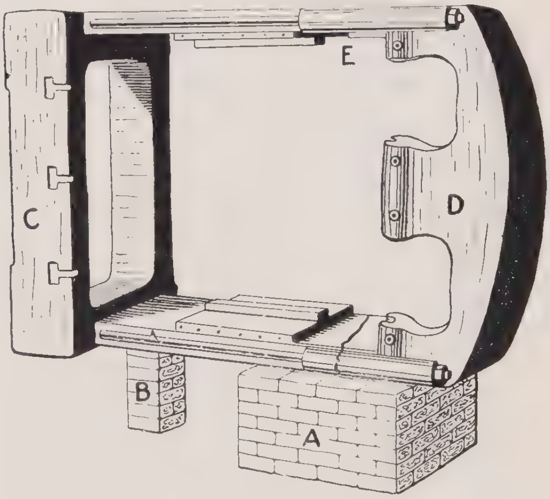


Figure 16—This is the Manner in Which a Heavy Die Press Casting Was Welded. It is not the Best Way to Preheat this Casting. As Described in the Text Preheating Should Take Place at Both A and E Simultaneously with the Casting Lying Upon Its Side and the Weld Made Vertically.

Welding a Cast Iron Fly Wheel

The welding of broken fly wheels, or gear wheels of cast iron, always present some problems which must be given careful consideration before the job is started. In Figure 17 such an instance is shown in the sketch where three spokes were broken from a fly wheel having six spokes in all. The breaks occurred at 1, 2, 3 and 4, as shown. The spokes at the breaks were approximately four and one-half inches in thickness and were oval in shape. In this instance the casting was laid flat upon its side and properly supported around the rim and under the hub with firebricks. A firebrick furnace was constructed around the rim at X, and another small furnace around the rim at N; these furnaces were partly filled with charcoal and the charcoal lighted with a torch. The furnace in each case was then covered with a sheet of asbestos paper and the rim expanded by heating it to a faint red.

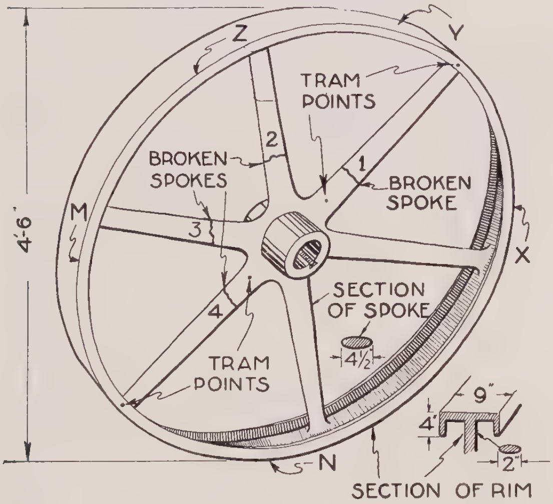


Figure 17—This Sketch Shows an Interesting Example of a Very Good Method for Preheating a Broken Cast Iron Fly Wheel. Preheating Fires were Built at N and X and the First Spoke Welded. Fires Were then Built at N and Y and the Second Spoke Welded, then at N and Z and the Third Spoke Welded and at M and N While the Fourth Spoke was Being Welded. This Method is Fully Described in the Text.

It will be noted that the portion of the wheel which was not broken consisting of the rim N-X, the spoke N, the spoke X, and a portion of the hub of the wheel constitute a solid section in the form of a triangle. It would not do, therefore, to place the fire on the rim between the spokes N and X, because if this were done, the expansion would strain the hub and would be of no great advantage. A careful analysis of the situation will show that when the preheating fires were built at the points X and N, the rim expanded in this manner would separate the break 1, from one-eighth to three-sixteenths of an inch and would permit the welding of the break 1 without subjecting any part of the wheel to strains.

It should be understood, of course, that all of the breaks 1, 2, 3 and 4 had been bevelled to an included angle of 90-degrees, from the upper side, so that all of the welding could be accomplished without moving the wheel. Some carbon paste, or carbon putty, as it is often called, placed underneath the spokes and used as supports will enable the welder to make an excellent job of this kind. When the rim at the points N and X had been preheated to a faint red, the weld of spoke No. 1 was made. The casting was then allowed to cool somewhat and the preheating fire X moved up to the point Y and the rim again heated at the points N and Y. There was now a solid section, consisting of three spokes and two triangular sections of the wheel. The preheating fires at N and Y accomplished the same purpose, as the original fires at N and X, and permitted the welding of break No. 2. When this was finished, the casting was again allowed to cool somewhat, and the preheating fire Y moved up to the point Z. Fires were again started at N and Z and break No. 3 welded. In like manner the fire Z was moved up to the point M and fires again built at N and M to permit the welding of break No. 4. A little consideration of this method will show that it is entirely logical and can be utilized whether one, two, three or more spokes are broken.

Welding Broken Teeth in a Large Gear Wheel

The welding of teeth in a large gear wheel is a relatively simple matter, and where the wheel is of large diameter, it may sometimes be accomplished as shown in Figure 18. To place this whole wheel in a preheating fire would be a difficult job, and the amount of heat involved would be considerable. Furthermore, the teeth would have to be built up vertically if the wheel was flat on its side and this would make the welding operation more difficult. The job can

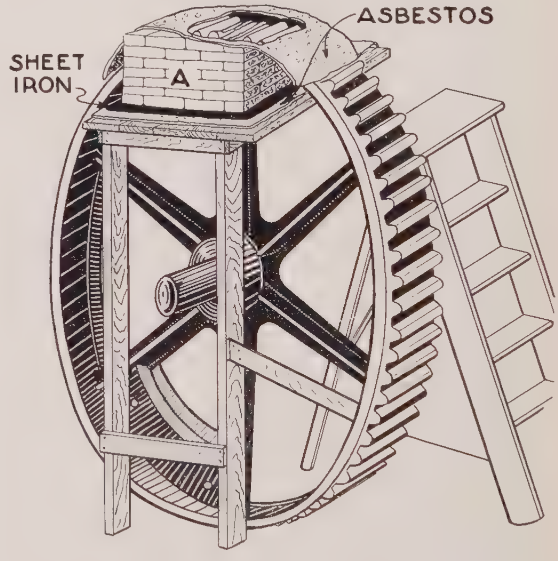


Figure 18—Sketch Showing a Method of Preheating a Large Cast Iron Gear Wheel, Where Several Pieces which Have Been Broken Out Must Be Built Up with the Torch. While This Method of Preheating Does Not Conform Exactly to the Theories Which Have Been Given with Reference to Other Wheels, in Some Cases It Will Serve the Purpose.

be done, as illustrated in Figure 18, by building a preheating furnace under the top rim of the wheel, where the broken teeth are located, and supporting this furnace upon a temporary scaffold built out from the side of the shop, or supported from a runway or by additional legs not shown in the sketch.

Over the wood platform, a sheet of asbestos is placed and on top of that a piece of sheet iron. Firebricks are laid on top of the sheet iron and a charcoal fire built in the furnace thus constructed. Asbestos paper forms a cover over the top. Preheating in this manner is not strictly according to theory, and expands only the rim and not the hub of the wheel, but the mass of the wheel is so great, and the diameter so large, that the heat is dissipated to a large extent and no serious expansion strains are set up when teeth are built up in this manner.

The teeth may be built up to shape by using carbon blocks, cut to the contour of the teeth, putting one on each side of the tooth on which the work is being done and building up the metal between the blocks. A skillful welder will often build a tooth near to its correct contour by manipulation of the torch and without the use of carbon blocks or other aids. But where teeth are as heavy as they are in the casting shown in Figure 18, such assistance will be found valuable and will enable the welder to do the job more quickly. After welding, the teeth are filed or ground to the proper shape which, in a heavy gear of this kind, is often sufficient. If the teeth must be again cut to their proper shape, they are built up a little wider and deeper than required for a finish.

Cutting Cast Iron

For a good many years it was thought that cast iron could not be cut and the reason usually given was the interference of the graphite flakes, interspersed in the iron, to the action of the cutting jet of oxygen. As explained in Lesson No. 4, oxy-acetylene cutting is a chemical action, that is, oxygen combines with the iron to produce iron oxide. In cast iron, the iron combines with the oxygen in similar manner, but the action is interfered with and retarded by the presence of the carbon in the form of graphite. Therefore, cast iron is much more difficult to cut than steel, the action is slower and cutting must take place at a considerably higher temperature. In steel, oxygen will combine with the metal and start the cutting action at a temperature of about a bright red heat. In cast iron, however, the temperature must be closely approaching the melting point, before the reaction becomes active and violent.

It is therefore, necessary in cutting cast iron for the man to be protected against the heat to a much greater extent than in cutting steel. In cutting heavy sections of cast iron, the reflected heat from the metal is very great and the operator must be dressed so that he will be able to withstand this heat, if he is to continue cutting. The fumes and smoke in cutting cast iron are much greater than in cutting steel. It requires about four times the length of time, about five times the amount of oxygen and about ten times the amount of acetylene to cut cast iron than steel. Of course, these figures will vary to a great extent, depending upon the grade of the iron. A good grade of cast iron used for machines will often cut with comparative ease, and the kerf will be relatively clean and smooth, but the poorer grades of cast iron, like grate bars, window weights and low grade iron castings may be cut only with great difficulty. In cutting low grade cast iron, the welder often resorts to the use of a steel rod to assist the cutting action. The rod is inserted in the cut and is, of course, consumed by the oxygen of the cutting jet, thereby increasing the heat along the line of cut to a very great extent. This practice of using an auxiliary steel rod is optional of course with the welder, but will always assist the cutting action. If heavy sections of cast iron are being cut, the rods may be three-quarters or one inch in diameter, or any pieces of steel may be used.

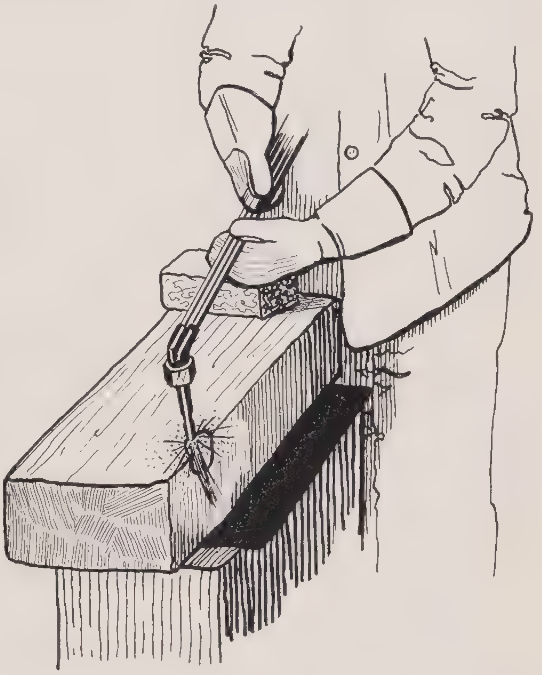


Figure 19—Sketch Showing the Beginning of a Cut in Cast Iron. The Torch Should Be Held Slanting Backward Away from the Direction of the Cut.

Cutting cast iron is accomplished by using a considerable excess of acetylene in the preheating flame, thereby delivering more acetylene down along the line of cut, which is consumed by the oxygen and more heat thus developed. It is necessary to raise the temperature of the iron nearly to the melting point in order to start the cutting action and to oscillate or move the torch from side to side in semi-circles, very much as was described for the semi-circular movement of the torch in welding. This movement of the torch, of course, increases the width of the kerf, or the slot which is being cut through the metal. It is necessary, however, to have a wide kerf in cutting a heavy piece of cast iron, particularly when cutting a poor grade of cast iron, and the edges of this kerf are usually rough and not clean and smooth, as is the case with steel.

The cost of cutting cast iron is so great that cutting is not ordinarily used in the iron foundry for cutting risers from iron castings. It is much easier and less expensive to nick these risers and knock them off by a blow from a ball swung from the crane, or if the castings are small, with heavy sledge hammers.

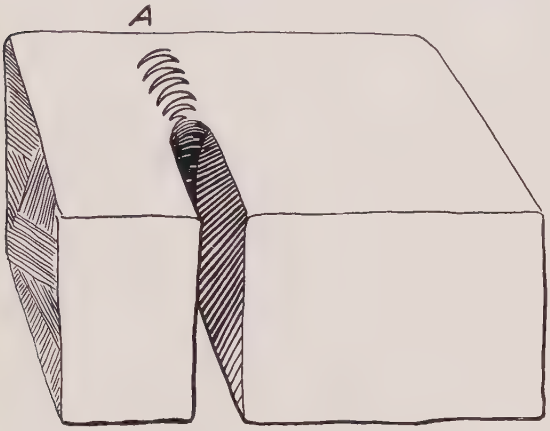


Figure 20—Sketch Showing the Oscillating Motion of the Torch During Cutting. There Is Considerable Lag or Slant of the Face of the Cut Away from the Direction of Cutting. When the Far Edge of the Piece at A Is Reached, the Torch Is Moved Over the Edge and Down the Far Side of the Bar to Cut Away the Lag.

Figure 19 shows the manner in which a cut in a cast iron block should be started. The torch is held, as illustrated, slanting backward from the direction of cut, and with the preheating flames lighted and a considerable excess of acetylene, the upper corner of the casting is heated until molten. The cutting jet is then turned on by pressing the cutting lever button and the pure oxygen is projected against the molten corner; at the same time the torch is straightened up slightly to allow the cutting jet to penetrate slightly into the corner of the metal. If the temperature is hot enough, cutting reaction will begin and the oscillating movement of the torch backward and forward should be started. If the cutting action does not start, or is momentarily lost, the cutting jet should be turned off and the torch held still, for a moment, to increase the temperature of the metal in the line of cut. When it has again reached the point of fusion, the jet should be turned on and the operation repeated until the cut is thoroughly started. Before actually starting the cut, the welder should heat the vertical side of the casting down along the line of the cut until it is all thoroughly heated; and it is often good practice to heat across the top of the section for a few inches along the line of cut, so that when the cutting action actually starts there will be less resistance from the cold metal.

Table Giving Approximate Oxygen Pressures Required to Cut Various Thicknesses of Cast Iron

Thickness in Inches of Cast Iron to Be Cut	Oxygen Pressure Required. Pounds Per Square Inch
½	40
¾	45
1	50
1¼	55
1½	60
1¾	65
2	70
3	80
4	90
5	100
6	110
8	120
10	150

As the cut progresses across the casting, the torch may in some cases be straightened up so that the tip is nearly in a vertical position, but there will always be considerable lag to a cast iron cut and it is often better to keep the torch pointing slightly backward. During progress of the cut, the oscillating motion of the torch is maintained backward and forward across the cut. Sometimes a black spot in the molten slag, which is running down the cut, will be encountered and it will seem impossible to cut through or dislodge it.

It is a part of the metal which is too cool to burn, and must either be heated or worked around if it is to be dislodged. Sometimes the cutting jet may be cut off for a moment and the preheating jet held steadily over the black spot. The cutting jet is then turned on and the cutting reaction again started. The operator will actually have to cut cast iron to appreciate this description of the process but after a little practice he will find that cutting cast iron is relatively easy. As the torch progresses across the casting and reaches the far edge, it is carried down the vertical side of the casting at this point still slanting backward in the opposite direction from the line of cut and the lag is cut through.

Cutting Boilers for the Installation of Stokers

The cast iron cutting, which the average shop will be called upon to do, does not usually consist of heavy sections of cast iron, but of lighter cast iron plates used in buildings and upon machinery, where alterations require the removal of a part of the plate. Cutting heavy pieces of cast iron is ordinarily confined to the larger steel plants, foundries, mining and refining plants and the cutters are trained for this class of work. As a matter of fact, the cutting of a heavy section of cast iron is not as difficult as the cutting of cast iron plate an inch or more in thickness.

An example of the cast iron cutting, which is most common, is shown in Figure 21. It was impossible to get a photograph of this job and, therefore, a sketch has been made. Two seventy-two inch by eighteen foot boilers, requiring 1,000 pounds of coal per hour, had been installed in a laundry plant. These had been in operation several years when it was decided to equip the boilers with a stoker. In order to make this installation, a portion of the lower part of the front plates of the boiler had to be cut away. These plates were about one-half inch in thickness, except at both ends of the cut, where the thickness was increased to three-quarter inches. There was also a one-inch band, or cap plate, in the center between the furnace doors. The total length of the cut was nine feet eight inches. This rectangular opening cut in the lower plate of the front of the furnace, shown by the dotted line in Figure No. 21, permitted the installation of the stoker.

The gauge pressure of the oxygen at the beginning of the cut was sixty pounds and of the acetylene fourteen pounds. The oxygen pressure was, however, increased from time to time during cutting until a maximum of ninety pounds was reached. The iron was dirty and cutting difficult. The total time required to cut the section out was sixty-five minutes. It took, however, approximately two hours to set up the equipment and complete the work. The cost of the job was approximately as follows:

140 cu. ft. of oxygen at 2c per cu. ft.	$2.80
97 cu. ft. of acetylene at 3½c per cu. ft.	3.40
Labor—2 hours at $1.00 per hour	2.00
Total	$8.20

It required between six and seven minutes to cut one linear foot of cast iron plate. The cost was approximately eighty-four cents per linear foot of cut made.

The cost of this cutting is, of course, high, but cast iron under these conditions is always more difficult to cut than if it were placed conveniently where a man could get at it. If these plates had been steel, instead of cast iron, a conservative estimate for the speed of cutting would have been approximately one foot per minute. On this basis and using the same unit figures given above, the cost would have been about eight cents per linear foot, or one-tenth as much as it cost to cut the cast iron.

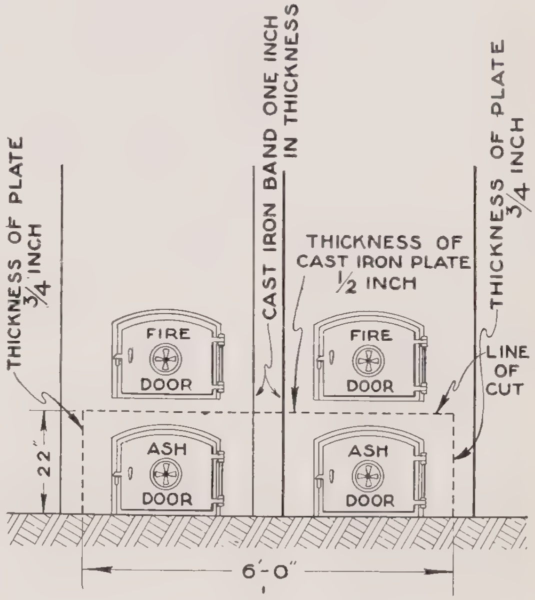

THICKNESS OF PLATE 3/4 INCH
CAST IRON BAND ONE INCH IN THICKNESS
THICKNESS OF PLATE 3/4 INCH
THICKNESS OF CAST IRON PLATE ½ INCH
FIRE DOOR
FIRE DOOR
LINE OF CUT
22"
ASH DOOR
ASH DOOR
6'-0"

Figure 21—Sketch Showing the Front Elevation of the Boiler. The Cut Through the Cast Iron Plate is Indicated by the Dotted Line.

These figures are given, so that the welder will recognize that he cannot expect to cut cast iron with the same ease and low cost with which he cuts steel. In undertaking a job of this kind, he must figure carefully the time required and the gases consumed before attempting it.

Job Sheet No. 14

Fusion Welding Two Pieces of Cast Iron

In this job sheet the student will weld two pieces of cast iron by the fusion process. Procure for this work a supply of pieces of cast iron one-quarter or three-eighths inches in thickness and approximately six inches long. The usual welding equipment should be connected up and a tip the size of the No. 5 placed in the welding torch handle. Besides this a supply of one-quarter inch cast iron welding rods and a can of cast iron flux will be needed.

Prepare the edges of the pieces to be welded by bevelling them to an angle of approximately 45-degrees; when this is done, line the two pieces up on a couple of firebricks. Properly adjust the regulators and light the torch. Before starting to weld, heat the entire piece of cast iron slightly by directing the envelope of the flame against the pieces of cast iron and moving it from place to place. By doing this, the entire piece will be warmed and the heat will not be radiated away from the weld so rapidly.

When the pieces have been slightly warmed, bring the luminous cone near to the metal at one end of the vee and heat the metal until it becomes molten. Just before the metal reaches this state, however, one end of a piece of welding rod should be held in the flame momentarily to heat it up and then plunged into the can of flux, where the heat will cause some of the flux to adhere to the end of the rod. When the metal in the vee has become molten, bring the end of the welding rod again into the flame and after it has been heated, place the end of the rod in the molten metal and allow some of the metal to melt from the rod. Note that the flux which covers the end of the rod causes the oxide on the molten metal momentarily to disappear. When welding cast iron, the welding rod should be moved in semicircles from side to side, so as to mechanically aid the chemical action of the flux in breaking up the oxide and also to make the weld more uniform in appearance. The motion of the rod will also break up some of the gas-holes which form in the hot puddle.

As has already been stated in the text, when making a cast iron weld, the welder should completely fill a short space of the vee. say one or two inches, before proceeding further.

Upon completion of his first cast iron fusion weld, the student will usually find that the top surface of the weld is covered with a number of small gas-holes or blow-holes. These are caused by the impurities in the weld metal, which the welder has not worked out, resulting in the formation of gas which cannot escape during welding. These holes can be almost entirely eliminated by careful puddling with the welding rod and by the use of good welding flux.

After the weld is completed and cooled, the student should place the piece in a vise, so that the weld is in the center of the vise and in a vertical position. He should then break the piece directly across the weld and note whether or not the weld metal has been thoroughly fused to the side of the vee, and if gas-holes are present in the weld metal. The student should continue welding these pieces until he can produce a well-fused, neat appearing weld.

Questions:

1. What causes hard spots in a cast iron weld?
2. Should the edges of the pieces of cast iron that are to be welded be melted to the desired bevel, or chipped?
3. What is meant by preheating?
4. Why is it done?
5. Is partial or complete preheating best in most cases? Why?
6. How should a piece of cast iron that has been preheated and welded be cared for immediately after welding?
7. Why is it necessary to use a good flux when welding cast iron?
8. What difference is there between cutting cast iron and cutting steel with the oxy-acetylene torch?
9. Is welding rod ever used when cutting with the oxy-acetylene process? Why?
10. What causes gas-holes or blow-holes in a cast iron weld? How can they be reduced in number?

Lesson No. 15

Brazing and Silver Soldering

IT IS believed that brazing and silver soldering will become more and more important in joining metals with the increasing use of copper, brass and bronze alloys and alloy steels. As stated in previous lessons, bronze welding and brazing are identical processes, to which different names have been given. The term "bronze welding" is usually applied to joining cast iron, malleable iron and steel. The term "brazing" is used particularly for the joining of brass, bronze and copper parts, and the various alloys, such as stainless steel, which are rapidly coming into common use.

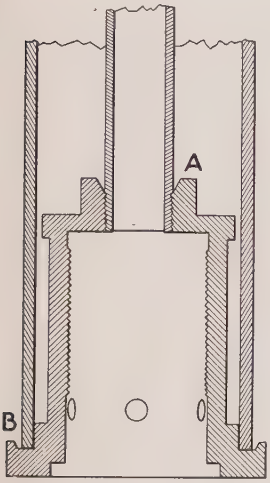


Figure 1—Sketch Showing the Handle and the Oxygen Tube of a Welding Torch. The Head and the Handle are Made of Monel Metal, and the Oxygen Tube of Brass. The Tube is Threaded into the Monel Metal Head, as Shown at A, and a Very Small Groove, the Smaller the Better, Machined at the Top of the Opening. This Groove is Filled with Silver Solder. The Handle is then Fitted Over the Head at B and the Little Groove Shown in the Head Filled with Silver Solder. Small Tight Fitting Joints are Much Better than Large Loose Joints.

The process of brazing may be clearly defined as one in which the parts being joined are heated to a red heat and are not melted, but the brazing alloy used to join them is actually fused. It is obvious that this can only be done where the melting point of the brazing alloy is lower than the melting point of the parts being brazed. There are a considerable number of good brass and bronze rods available which can be used for brazing purposes, some of which are listed in the table upon page 164, Lesson No. 11. There are, of course, other brazing rods, one of which is phosphor copper, which will be described in detail later in this lesson.

Some of the most useful of the brazing alloys are the group of silver solders which are available in wire and sheet form. Silver soldering is really brazing, but its importance is such that it is dealt with separately in this lesson. The most useful flames for both brazing and silver soldering are those produced by oxygen and acetylene, or by acetylene and air. An objection often heard to the use of oxygen and acetylene for brazing purposes is the very high degree of heat produced. The welder often forgets, however, that this heat is under his absolute control by moving the torch further away from the work and that in this manner it can be varied to suit his requirements. Acetylene and air produces an excellent flame and a high degree of heat. There are many other gases which, combined with oxygen, produce excellent soft flames and included in these are hydrogen, city gas, Shellane, Skell gas, Philfuel and the

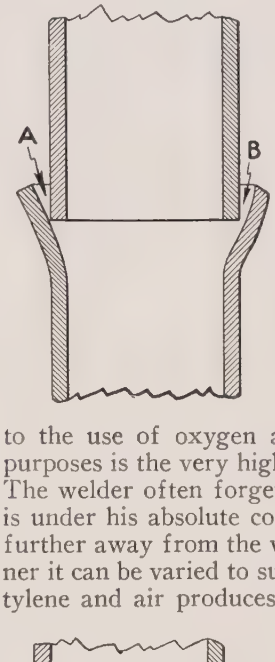


Figure 2—This Sketch Shows Two Pieces of Tubing Fitted Together for Silver Soldering. The Groove A is too Large and the Fit at B is so Bad that the Silver Solder would Run Through the Joint and Down the Lower Tube. This would be a Particularly Difficult Joint to Silver Solder, Because of the Looseness and Irregularity of the Fit.

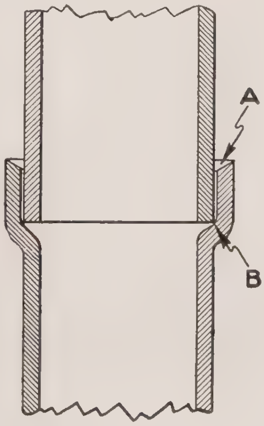


Figure 3—This Type of Joint is Well Prepared for Silver Soldering. The Edge of the Upper Tube at B is in Contact with the Lower Tube and Will Prevent the Silver Solder from Running Through the Joint. The Fit is Tight and the Groove at A is just Enough to Enable the Welder to Melt, conveniently, the Silver Solder Around the Joint.

many other oil gases upon the market. Many of these can be used through standard oxy-acetylene torches and give excellent results where the temperature produced is sufficiently high for the purpose.

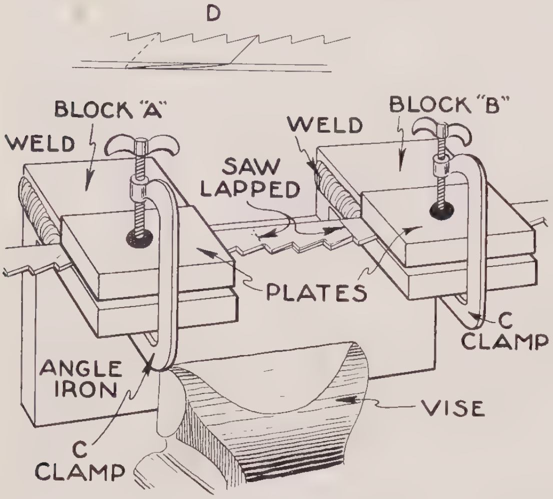


Figure 4—Sketch Illustrating a Convenient and Easily Made Jig for Welding Band Saws. The Jig is Made of a Piece of Angle Iron Cut as Shown, Using Plates and C Clamps to Hold the Saw in Place. The Saw is Scarfed and the Scarfed Portion is Bent Slightly in the Middle, as Shown in the Small Sketch D, Each of the Ends Being in Contact. The Braze is Easily Made and the Finished Job is Shown in Figure 7.

Table No. 1

Principal Metals Upon Which Silver Solder Is Used and Their Respective Melting Points

Metal	Melting Point In Degrees Fahrenheit
Nickel	2640
Steel (Medium Carbon)	2600
Stainless Steel	2600
Monel Metal	2400
Copper	1980
18% Nickel Silver	1955
Bronze	1650
Yellow Brass	1650
Sterling Silver	1650
Extruded Brass	1580

Silver Soldering

The silver solders are alloys of silver, copper and zinc. The percentages of these various metals determine the color of the alloy, its strength and its melting point. Cast silver solder has a strength of from 40,000 to 60,000 pounds per square inch. In silver soldering various parts, the welder must select a silver solder which will have a melting point enough lower than that of the metal being joined to avoid heating the parts to a temperature too close to their melting point.

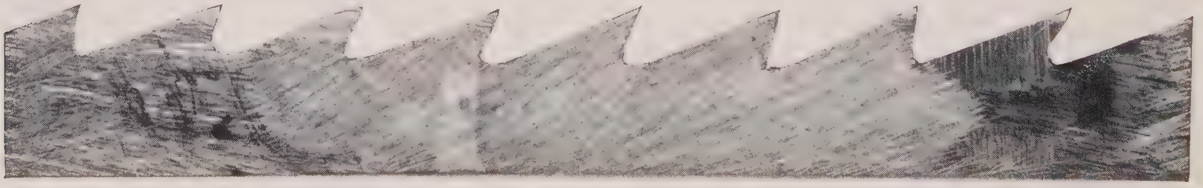


Figure 7—Photograph Showing a Brazed Joint in a Band-Saw. The Lap Includes Three Teeth to the Right of the End of the Braze, Indicated by the Light Colored Area Across the Saw.

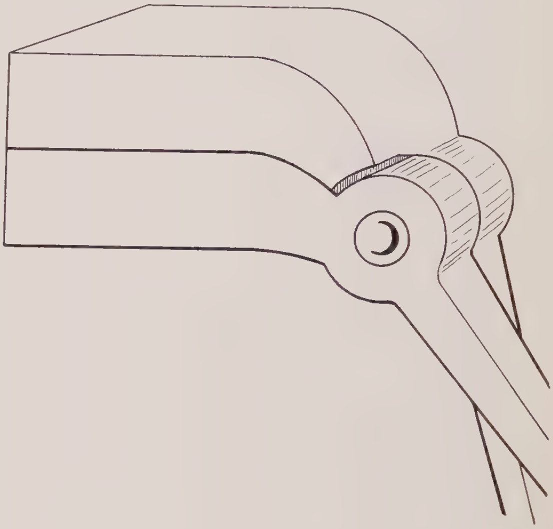


Figure 5—Sketch Showing the Tongs Used for Heating. The Blades of the Tongs are Heated White Hot and the Band-Saw Gripped with the Hot Tongs for a Moment.

Silver solders are used for joining parts made of various metals, the principal ones being given in Table No. 1. Included in this table are the melting points of the metals, because these are very important factors in silver soldering.

When silver soldering joints, it is essential that the parts to be joined are clean. Cleaning can be done mechanically with a wire brush, or other means, or chemically with an acid solution. The parts should fit together snugly. A loose fit is undesirable, and a fillet built up around the joint is an unnecessary waste of silver solder, because the fillet does not materially strengthen the joint.

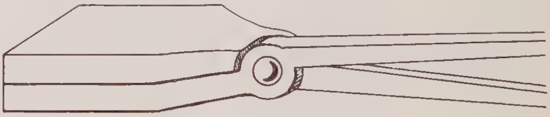


Figure 6—These are Cooling Tongs. They are Used to Grip the Saw Immediately After the Heating Tongs Have Been Removed. Pressure is thus Applied at the Same Time that the Braze is Cooled.

The fitting of the two pieces to be joined is a particularly important part of the process; care to make the joint tight and to leave a little groove at the top of the joint around which the melted solder may be flowed will greatly assist in making the job easy.

It is common practice in the manufacture of welding and cutting torches to silver solder the tubes into the head. In Figure 1 a sketch is shown of the handle and the tube of a welding torch and the head as they should be machined for silver soldering. The handle and the torch head are made of Monel metal. In Figure 2 two tubes are shown fitted together too loosely for good silver soldering. Figure 3 shows how this joint should be made to secure good results.

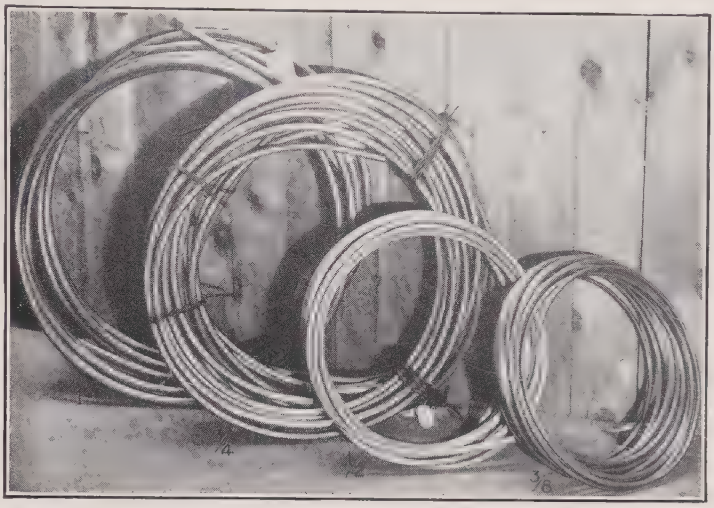


Figure 8—Photograph Showing Coils of Copper Pipe as This Pipe or Tubing is Supplied by the Chase Brass and Copper Company. This Tubing can Easily be Bent by Hand.

The use of proper flux is important; for most purposes borax will be found excellent. There are several methods for applying borax, the most simple of which is to mix the borax with cold water to make a thick paste. A better method is to mix the borax with hot water and keep the solution hot while applying the flux to the work. A third method is the melting of the borax, allowing it to cool and crushing it into a powder. This powder is then mixed with alcohol and kept in a closed container.

Table 2—Silver Solders*

Table showing melting points in degrees Fahrenheit, colors and metals upon which the various grades are used.

These are arranged in the order of their silver content, No. 1 having the lowest silver content and No. 12 the highest.

No.	Color	Melting Point	Used to Solder the Metals Given Below
1	Brass yellow	1600	Strong joints for heavy parts where melting point is suitable.
2	Brass yellow	1500	Extruded brass, copper, iron, steel or nickel parts.
3	Brass yellow	1575	Strong solder with low zinc content and high melting point.
4	Pale yellow	1450	Good intermediate solder.
5	Pale yellow	1435	Stainless steel. Matches color.
6	Pale yellow	1445	Monel metal and nickel where color is not important.
7	Yellow-white	1370	Small parts, particularly copper. Band saws.
8	Yellow-white	1340	Monel metal and nickel. Nearly matches color.
9	Yellow-white	1425	Similar to No. 8.
10	Silver-white	1325	Copper nickel and Monel metal tanks. Resists corrosion.
11	Silver-white	1425	Contains silver and copper only.
12	Silver-white	1460	Very high silver content. Makes strong, ductile joints.

**From Handy Book of Silver Solder published by Handy and Harman, Bridgeport, Conn.*

In some instances when borax is used as a flux, it has a tendency to run away too rapidly when melted. This action can be retarded by mixing from one-tenth to one-half boracic acid to the borax before it is mixed in paste form. The boracic acid makes the flux thicker and more gummy, but somewhat raises the melting point.

Handy & Harman of Bridgeport, Conn., have made a specialty of silver solders for many years and have issued instructions for the use of silver solder in bulletin form. Almost every oxy-acetylene torch manufacturer has been familiar with silver soldering since the earliest days of torch construction. Torch heads have been silver soldered to tubes because they are usually in a zone of heat, during the operation of the torch, which is too high for a soft soldered joint. Silver soldering these metals is an easier process than brazing.

There are a good many other manufacturers of various commodities, including those making silverware, who use silver soldering to a considerable extent, but the welder heretofore has had very little information upon the subject. If his judgment is correct in applying silver solder, he will find that it can be used to very great advantage for the metals given in Table 1.

Stainless steels are being used to a greater and greater extent as time goes by for the manufacture of milk handling apparatus, and for other equipment where absolute cleanliness and resistance to corrosion are requirements.

Stainless steels and other metals which form oxides, difficult to remove, can be soldered to good advantage with a flux made of one part of borax and one part of boracic acid, both being mixed with a solution of zinc chloride and water. The flux should be applied to the parts to be joined and the silver solder with a brush which will spread the flux to much better advantage than any other means; even application of the flux is important.

In preheating the parts, if one is heavier than the other, the heavier part should receive the most heat. The heat conductivity of metals differs to a considerable extent, as shown in the table on page 16, Lesson No. 2. It is, therefore, necessary to preheat the surrounding parts of metals having a high heat conductivity to a greater extent than those of low conductivity. The heat of the metal along the line of the joint is the principal factor in silver soldering. The temperature must be right; to enable the student to visualize heat colors, the color chart on page 109, of Lesson No. 7, should be very carefully studied and these colors memorized in relation to the temperatures given. The melting temperatures of the silver solders used should also be memorized.

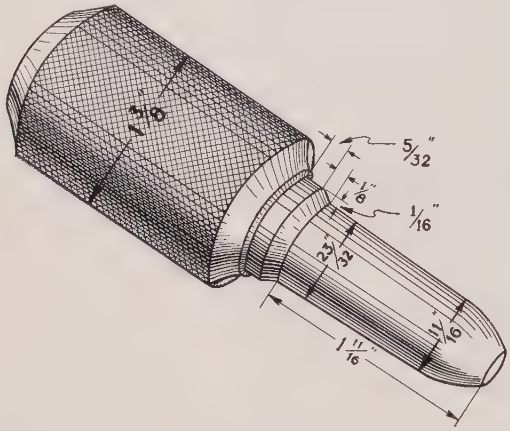


Figure 9—Sketch Showing the Flanging Tool Used to Flange the Copper Tubing the Shape of a Bell. Dimensions are Given Upon this Sketch for Three-Quarter Inch Water Tubing of the Wall Thickness Given in Table 3.

If an oxy-acetylene torch is used, it is important that the welder realize the very high degree of heat which he has in the flame and use only the secondary envelope of the flame and not the luminous cone. If the luminous cone of flame is brought into close contact with the parts to be silver soldered, and the silver solder itself, both metals will be burned. If flames produced by the burning of oxygen and city gas, or by city gas and air are used, the temperatures are much lower and there is less danger of overheating the metal. Acetylene and air produce a high degree of heat and are, as heretofore stated, excellent for silver soldering. The flame is not as hot as the oxy-acetylene flame, but is considerably hotter than that produced by air and city gas.

Table 3

Dimensions and Weights of Chase Copper Tubing

Nominal Size Inches	Outside Diameter Inches	Wall Thickness Inches	Pounds Per Lineal Foot
⅜	.500	.049	.269
½	.625	.049	.343
⅝	.750	.049	.418
¾	.875	.065	.640
1	1.125	.065	.838
1¼	1.375	.065	1.04
1½	1.625	.072	1.36
2	2.125	.083	2.06

Whichever flame is used, care must be taken to see that the temperatures are correct. When the temperature of the parts is equal to the melting point of the silver solder, the silver solder is melted into the joint using it in strip form, much as a welding rod is used. It may be formed into a ring of silver solder, if desired, and slipped into the joint previously. When it is thoroughly fused, it will run into the joint, even though the parts fit tightly together. It is essential to flow the solder around the joint as quickly as possible. Borax will fuse or become fluid at approximately 1400 degrees Fahrenheit, and this will be found an excellent indicator of the temperature of the metal.

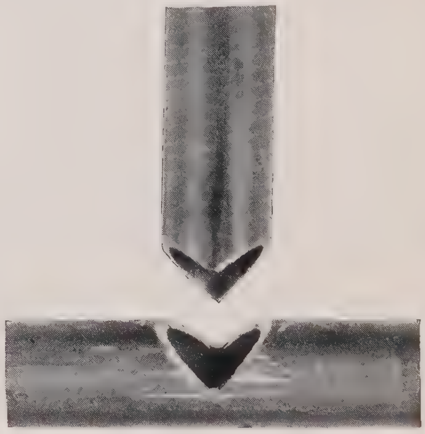


Figure 10—The Copper Tubing for the Tee Joint is Cut with a Hack-Saw as Illustrated.

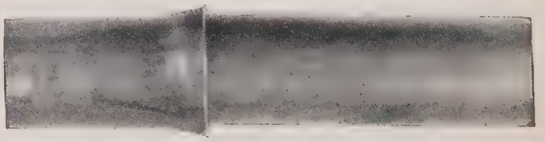


Figure 11—The Ends of Two Pieces of Copper Tubing, the One Inserted into the Bell Shaped Flange of the Other. The Tube with the Larger End was Formed in this Manner with the Flanging Tool Shown in Figure 9. This Joint is Ready for Brazing.

In silver soldering stainless steel, it is necessary to heat this metal to a bright red heat, as indicated at No. 6, Color Chart No. 6, Lesson No. 7, the temperature of which is 1550 degrees. Despite the fact that the No. 5 silver solder given in Table 2, and recommended for silver soldering stainless steel, melts at 1435 degrees, it is necessary to heat stainless steel to a bright red heat before the solder will join or amalgamate with it.

In silver soldering it is good practice to so regulate the light in the room that it is uniform where the work is being done. Accurate judgment of the color to which parts are heated is required, and with uniform light conditions this will be less difficult than if these conditions are constantly changing. Like other work of this kind, it is necessary to protect the parts from cold drafts of air, and this can be easily accomplished with suitable asbestos paper screens.

If the silver solder balls up, or bunches and does not flow readily, too little heat has been applied to the metal, or it has been poorly fluxed. The finished silver soldered joint should be smooth, even and uniform, without pinholes or other imperfections. If pinholes occur it is an indication of either dirt, oil or grit on the part before the job has been started, poor fluxing, or insufficient heat.

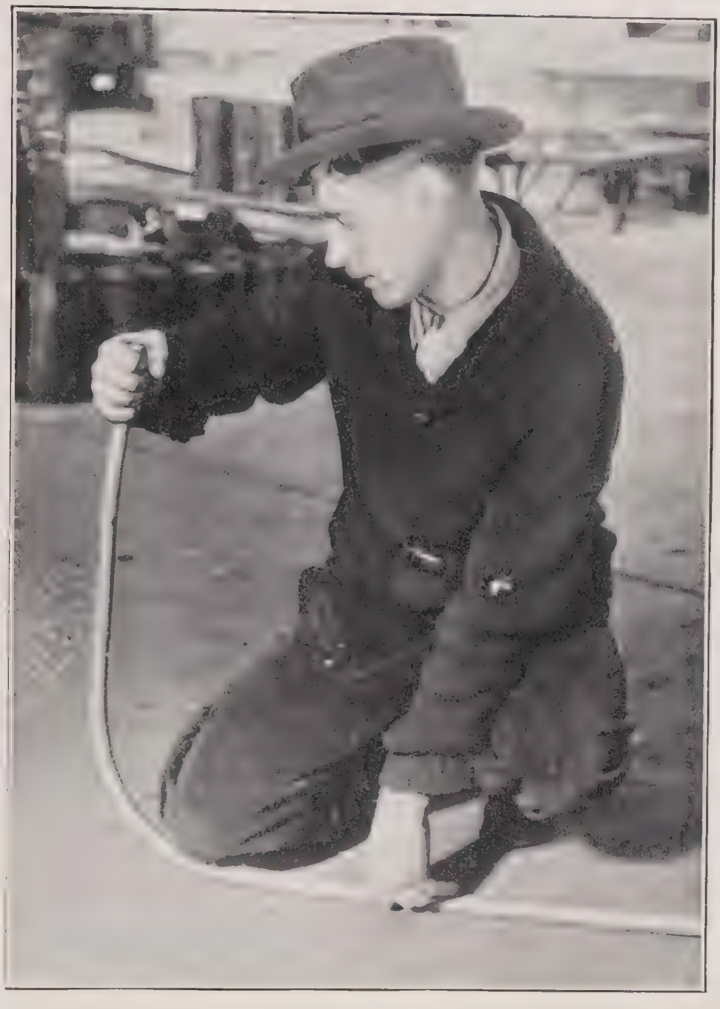


Figure 12—Photograph Showing the Ease with Which Copper Tubing is Bent. It may be Bent Around the Knee, or Around any Circular Object, having a Radius not Less than Four Inches, without Flattening.

Brazing and Silver Soldering Band Saws

A job, which frequently comes into the welding shop, is the repair of broken band saws. These are encountered to a greater extent in shops located in the lumber districts than elsewhere. Some of these saws may be very small, possibly one-eighth or three-sixteenths of an inch in width and some of them may be six or eight inches in width. The smaller saws may be encountered almost anywhere, where woodworking plants abound, and the larger saws will probably not be found, except in the districts where lumbering, as an industry, is extensive. Steel engineers' tapes can be repaired in almost identically the same manner.

The job may be accomplished either by brazing or silver soldering. A simple jig is required, which can be made in any welding shop, a very convenient one being shown in Figure 4. This consists of an angle iron with a section of the upper leg cut away and two pieces of bar iron welded to the parts of the upper leg which remain. These pieces are welded so that their front faces are in line. Two plates, which lie on top of the band saw, and two C clamps of the common welding shop variety, are all that are necessary to complete the jig.

The jig is placed in a vise, as indicated, and clamped tight. The ends of the band saw are thoroughly cleaned and placed in the jig with the back of the saw contacting with the steel blocks A and B. In this manner the band saw will be kept in line. The two ends should overlap about three teeth and the teeth should match up. The overlapped portion should be scarfed or bevelled and bent slightly so that there is more space in the middle of the lap than at each edge, as indicated in the small figure D.

Both surfaces are thoroughly coated with flux and a sheet of silver solder or soft brass, equal in size to the lapped surface, is coated with flux and placed between the ends of the saw. The clamping plates are placed over the saw and the C clamps drawn up tight until the saw is securely held in position. Borax and water may be used, as described, for silver soldering, or any good brazing flux for the brass joint. Two pairs of tongs are required to complete the job; one of these is illustrated in Figure 5, and consists of two heavy steel blocks welded to the tong handles in such manner that they will close tightly. This pair of tongs is called the heating tongs. The other pair, shown in Figure 6, is a smaller, flatter set of tongs, used to hold the saw blades in position while cooling.

The heavy tongs are heated to a white heat, with the oxy-acetylene torch and the lapped edges of the saw gripped between the hot plates. These are held for a moment, until the silver solder or brass plates are thoroughly fused, when the hot tongs are removed and the saw gripped with the cold tongs and held securely until the joint is cool.

Another way of accomplishing the same purpose is to use an oxy-acetylene torch, taking care to keep the luminous cone of flame well away from the joint and using only the envelope of the flame to contact with the metal. The saw blades are heated to a temperature at which the silver solder or the brass plate will fuse, and then gripped with the cold tongs and held securely until the joint is cool.

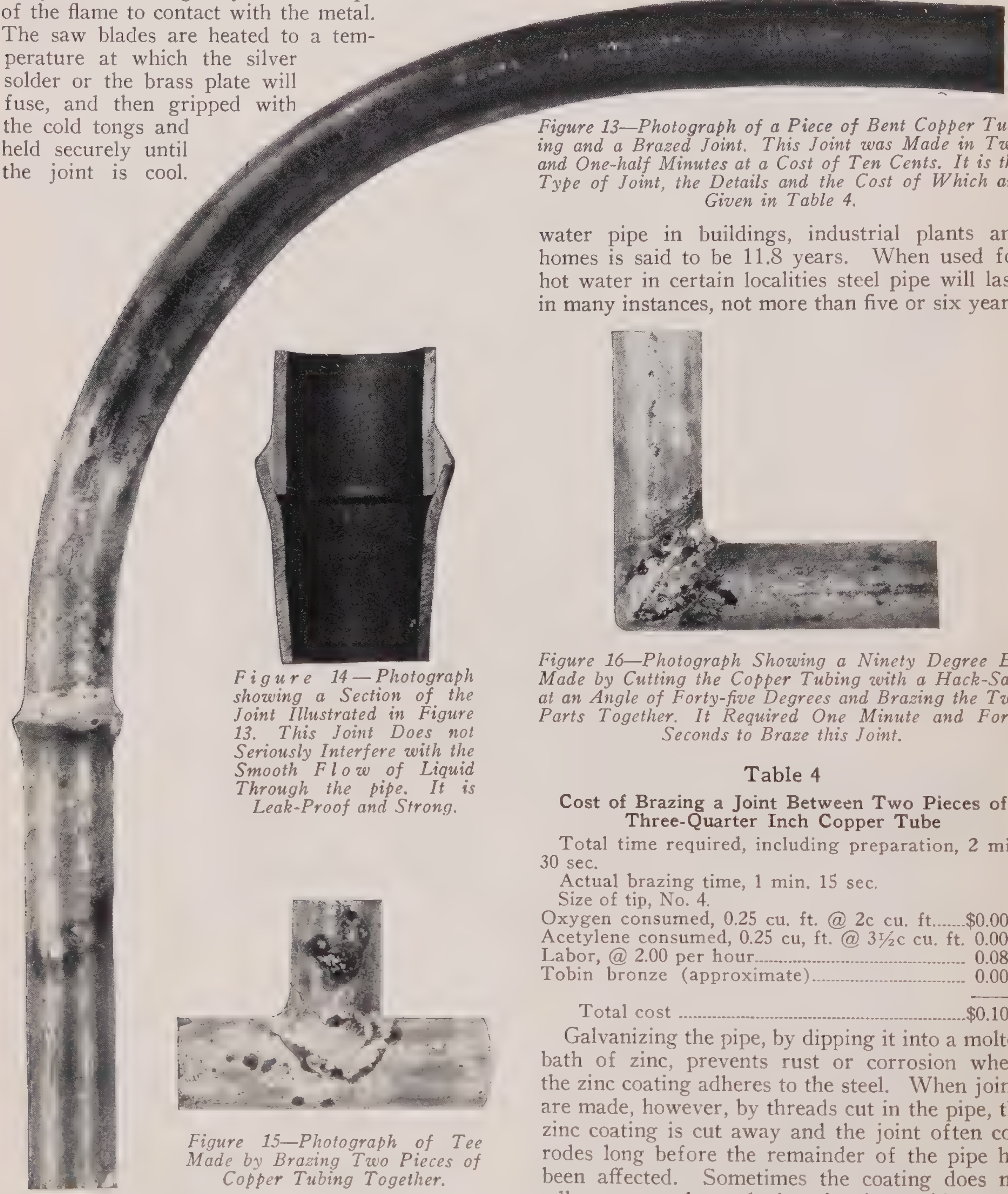


Figure 13—Photograph of a Piece of Bent Copper Tubing and a Brazed Joint. This Joint was Made in Two and One-half Minutes at a Cost of Ten Cents. It is the Type of Joint, the Details and the Cost of Which are Given in Table 4.

Figure 14—Photograph showing a Section of the Joint Illustrated in Figure 13. This Joint Does not Seriously Interfere with the Smooth Flow of Liquid Through the pipe. It is Leak-Proof and Strong.

Figure 15—Photograph of Tee Made by Brazing Two Pieces of Copper Tubing Together.

There is a patented brazing plate for acccomplishing a similar joint, consisting of a soft brass wirecloth sheet, which has been coated with rosin. This brazing plate can be procured in large sizes and a small piece cut off to fit the saw. The hot iron is applied in the same manner, as heretofore described.

Brazing Copper Pipe

The average life of iron or steel pipe used for water pipe in buildings, industrial plants and homes is said to be 11.8 years. When used for hot water in certain localities steel pipe will last, in many instances, not more than five or six years.

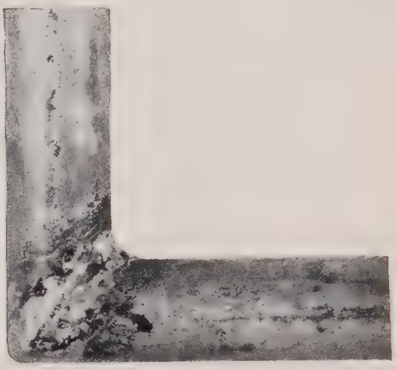


Figure 16—Photograph Showing a Ninety Degree Ell Made by Cutting the Copper Tubing with a Hack-Saw at an Angle of Forty-five Degrees and Brazing the Two Parts Together. It Required One Minute and Forty Seconds to Braze this Joint.

Table 4

Cost of Brazing a Joint Between Two Pieces of Three-Quarter Inch Copper Tube

Total time required, including preparation, 2 min. 30 sec.

Actual brazing time, 1 min. 15 sec.

Size of tip, No. 4.

Oxygen consumed, 0.25 cu. ft. @ 2c cu. ft.	$0.005
Acetylene consumed, 0.25 cu, ft. @ 3½c cu. ft.	0.0087
Labor, @ 2.00 per hour	0.0833
Tobin bronze (approximate)	0.003
Total cost	$0.10

Galvanizing the pipe, by dipping it into a molten bath of zinc, prevents rust or corrosion where the zinc coating adheres to the steel. When joints are made, however, by threads cut in the pipe, the zinc coating is cut away and the joint often corrodes long before the remainder of the pipe has been affected. Sometimes the coating does not adhere properly and the cleaning acid or the chloride from the flux, used in the galvanizing process, remains on the iron and causes it to corrode. Iron or steel pipe lines are at best more or less temporary and subject to frequent renewal either wholly or in part.

Copper and bronze on the other hand have been known to survive two thousand years of submersion in water. The permanence of these metals, therefore, make them ideal for the manufacture of water pipe and the ease with which joints in such pipe can be brazed makes copper and bronze pipe particularly useful for installation where long life is a requirement.

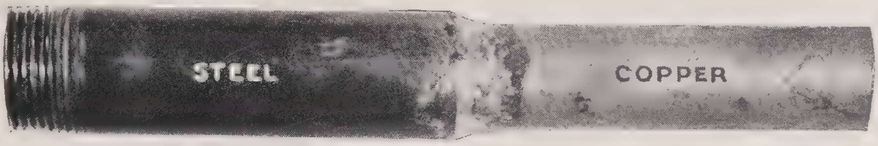


Figure 17—Photograph Showing a Joint Between a Steel Nipple and a Piece of Copper Tubing. This Joint was Brazed in One Minute and Twenty Seconds. It is Almost as Easy to Braze a Joint Between Steel Pipe and Copper Tubing as Between Two Pieces of Copper Tubing.

A development which has become of even more importance, when coupled with oxy-acetylene brazing, is the manufacture and distribution, by some of the larger brass companies, of copper and red brass pipe made in sizes for use by the plumber as water pipe and having thinner walls than pipe which is intended to be threaded. The copper pipe is very flexible and is furnished in twenty foot straight lengths and in coils as long as sixty feet.

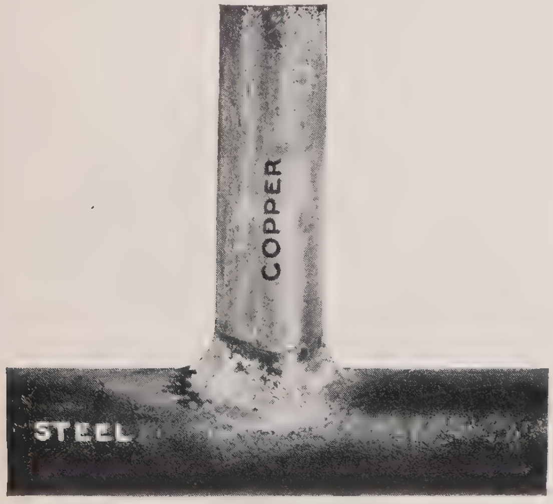


Figure 18—This is a Tee Joint Between Copper Tubing and Steel Pipe. It is a Similar Joint to the One Illustrated Under the Flooring in Figure 19. One Minute and Forty-five Seconds were Required to Braze this Joint.

The Chase Brass & Copper Co. of Waterbury, Conn., supply what is called copper water tubing, which was originally made and is supplied for use with compression fittings, that is, brass fittings which are machined and threaded in such manner that the ends of the copper tubing can be flanged in a bell shape and held tightly between the two parts of the fittings when screwed together. An example of this type of joint is very common on a small scale where the small copper tube from the vacuum tank on an automobile is connected to the carburetor. A compression fitting is almost always used to screw into the carburetor.

The tubing supplied for water pipe is deoxidized copper made from metal 99.9 per cent pure. It is annealed so that it will bend easily to any radius not less than four inches. It can be bent by hand, or bent using the knee, as shown in Figure 12. The American Brass Co. furnish what is known as "85 Red-Brass" having a copper content of 85 per cent and said to be very highly resistant to corrosion.

Chase copper water tubing is furnished in diameters from three-eighths inches to three-quarter inches inclusive in sixty foot coils, and in diameters from one inch to two inches in twenty foot straight lengths only. The dimensions, thickness

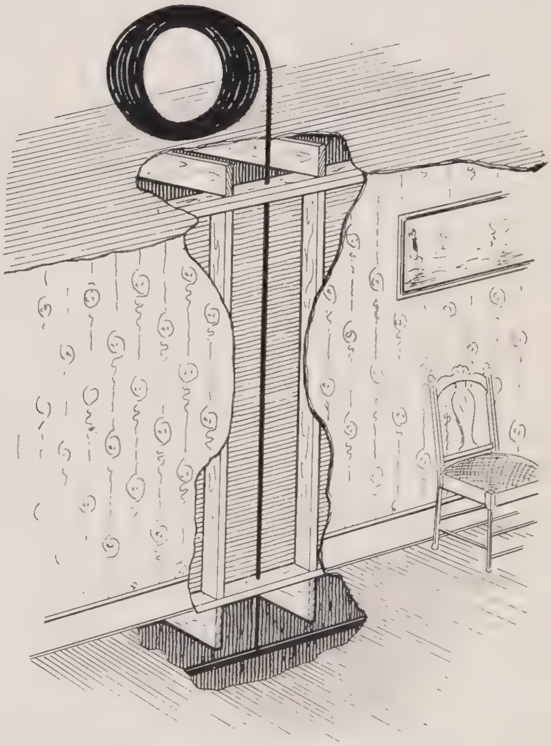


Figure 19—The Copper Tubing may be Slipped Downward Between the Plaster Walls of an Old House to Connect with a Pipe Line in the Cellar When a Rusted Section is to be Removed, or an Extension to be Made. The Tubing Comes in Sufficiently Long Lengths to Avoid the Necessity of Joints Between the Walls. The Joint Between the Vertical Copper Tube and the old Horizontal Steel Pipe in this Illustration is like that Shown in the Photograph Figure 18.

of the wall and weight per linear foot of this copper tubing are given in Table 3. While the walls of this tubing are much thinner than pipe used with screwed fittings, it is even stronger than much of this pipe. It will withstand approximately 3,000 pounds water pressure, which is from thirty to fifty times that of the ordinary city water pressure.

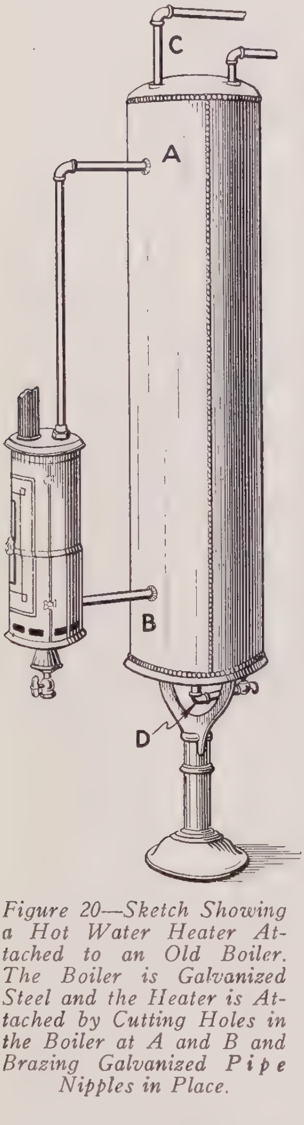


Figure 20—Sketch Showing a Hot Water Heater Attached to an Old Boiler. The Boiler is Galvanized Steel and the Heater is Attached by Cutting Holes in the Boiler at A and B and Brazing Galvanized Pipe Nipples in Place.

This pipe is very easily brazed, with bronze rods and A-Mal-Gam flux. Bronze having a high copper content should be used to make joints resistant to electrolytic corrosion.* A bronze rod having a copper content of 80 per cent and a zinc content of 20 per cent is more resistant to such corrosion than one containing a larger percentage of zinc. Everdur, an alloy of copper, silicon and manganese makes an excellent weld which would not be subject to galvanic action.

Brazing is a very simple procedure and the preparation of the pipe is quickly performed. It can be cut off with a hack-saw in a moment, and by using the flanging tool, shown in Figure 9, which is driven into the end of the pipe with a hammer, quickly flanged so that the end of the piece of pipe to be brazed to the flanged end will fit neatly into the flange, as illustrated in Figure 11.

A little flux paste made of flux and water is pasted over the joint made in this manner and the oxy-acetylene torch is used to heat the joint to a cherry red temperature, or approximately 1375 degrees. Bronze is then brought into the zone of flame and fused until the flanged end of the pipe is completely filled with the molten bronze. The bronze will run around this joint very rapidly and will freely flow upon and adhere to the copper.

A joint of this kind in three-quarter inch tubing can be made in two and one-half minutes at a cost of approximately ten cents. The cost of making such a joint is given in detail in Table 4. A tee can be made by cutting the pipe with a hack-saw, as shown in Figure 10, and brazing the branch to the main pipe, as illustrated in Figure 15. A vertical branch pipe from a horizontal pipe, where the brazing must be made overhead, requires about three minutes, whereas a horizontal tee, which can be turned to suit the convenience of the welder, can be brazed in approximately one minute and forty-five seconds.

A ninety degree brazed elbow is a very simple joint, because the cutting of the pipe with a hack-saw is quickly and easily done and when reversed the two parts fitted together will make a ninety degree elbow. Brazing around this joint is a very rapid operation. The photograph, Figure 12, has been taken especially to show how easy it is to bend copper pipe. It can be bent by hand around the knee, or around a larger piece of pipe, a post, or any other circular object. If the radius is not less than four inches, it will not flatten and the wall of the pipe will not be materially changed.

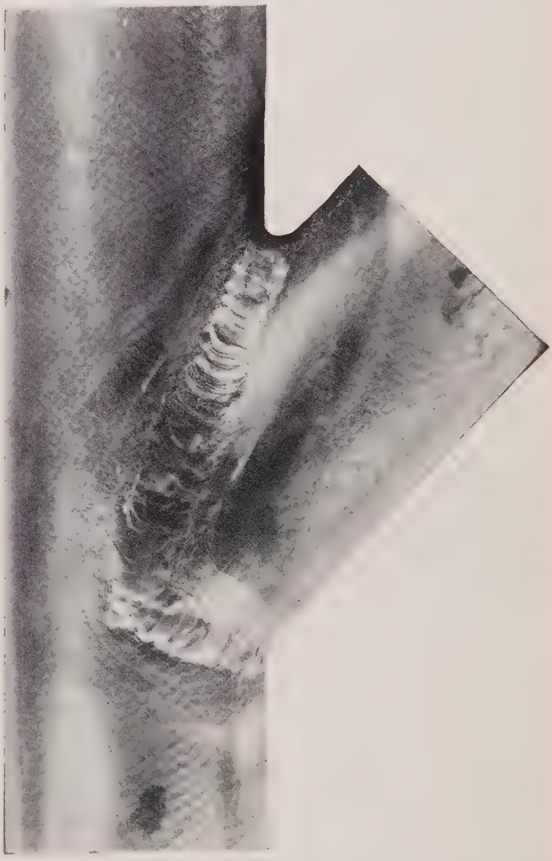


Figure 21—Photograph of a Brazed Joint Between Two Pieces of Four Inch Galvanized Iron Pipe. This is the Kind of Joint Which is Recommended in the Systems Shown in Figures 23 and 25.

Electrolytic corrosion, or electrolysis as it is often called, is a galvanic action which takes place when two different metals like copper and zinc, for instance, are placed together and subjected to dampness. It is also caused by stray currents of electricity which often travel along pipe lines, particularly water pipes.

the pipe, as well as the steel welding rod, the galvanized coating adjacent the joint will be burned away and the joint will be a plain steel joint, ungalvanized, and hence subject to corrosion and rusting in the same manner that plain iron or steel pipe would be. It is obvious, therefore, that to use galvanized pipe and to steel weld the joint makes the life of the pipe line equal to the life of the ungalvanized joint.

In brazing, however, the temperature of the pipe is not raised to the fusion point, but to a cherry red heat and Tobin bronze is fused upon and amalgamated with the steel and the galvanized coating. The galvanized coating is, of course, melted in the zone of heat, but it is reduced to an oxide which clings tenaciously to the pipe and is in itself a rust resisting agent. The bronze rod makes an excellent braze between two pieces of pipe, as is clearly shown in Figure 21. This is a photograph of a joint made in four-inch galvanized pipe, such as that frequently used for drain and vent pipes for plumbing systems in the larger buildings.

Engineers have upon occasion raised the question as to whether there would be a line between the bronze brazed to the pipe and the zinc coating, inside of the pipe, where the zinc coating would be entirely removed and that this line would represent a zone, or area, where rust would take place. Some engineers have thought that the melting points of the zinc coating and the Tobin bronze rods differ so widely that the bronze coating could not be joined to the zinc. They thought that the heat of the flame would burn away the zinc coating and that the bronze could not be flowed over this surface on the inside of the pipe. It might be very easy, they reasoned, to cover entirely the bare steel on the outside of the pipe, but the inside of the pipe presented problems which could not be taken care of in making a joint of this kind.

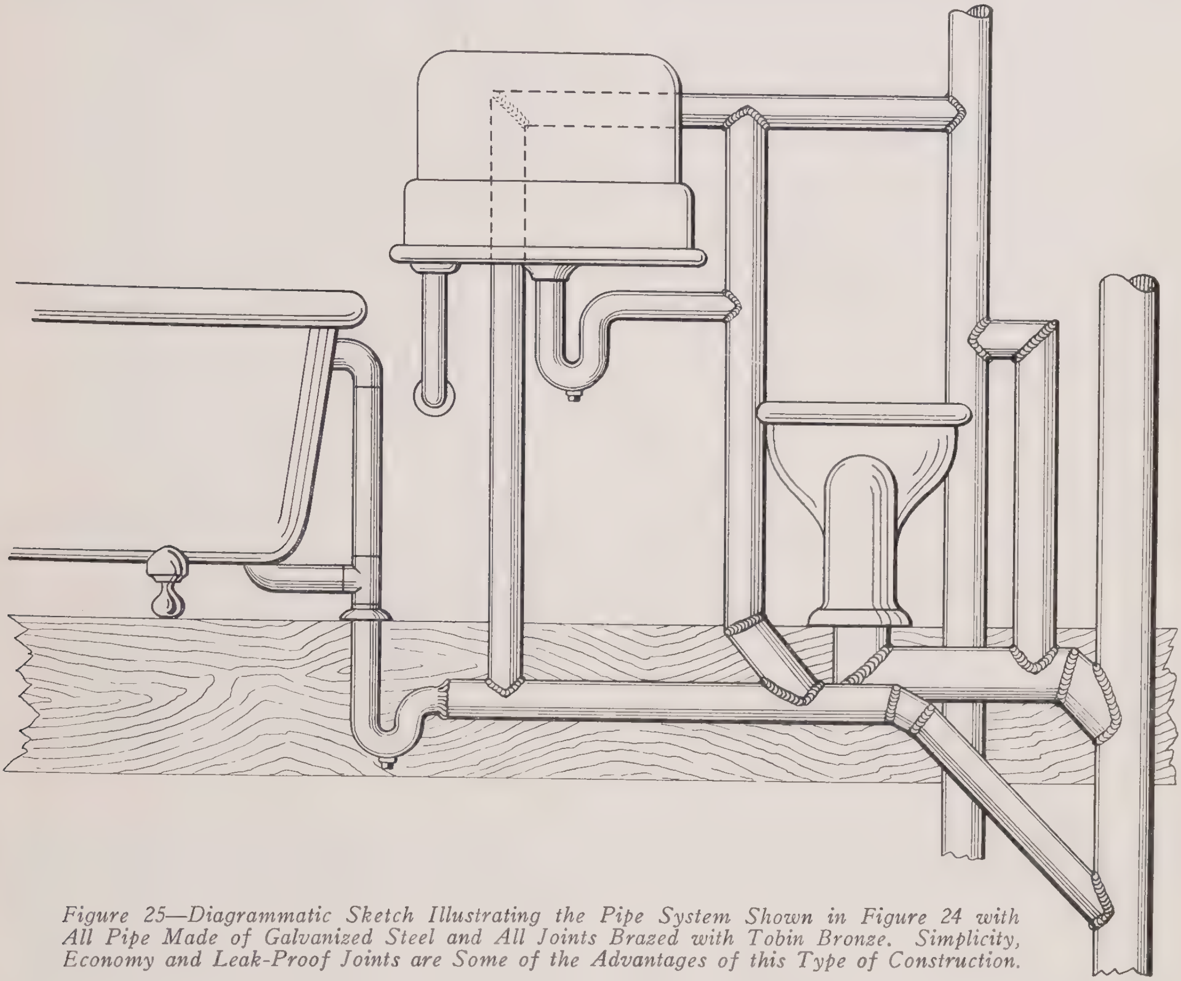


Figure 25—Diagrammatic Sketch Illustrating the Pipe System Shown in Figure 24 with All Pipe Made of Galvanized Steel and All Joints Brazed with Tobin Bronze. Simplicity, Economy and Leak-Proof Joints are Some of the Advantages of this Type of Construction.

As a matter of fact, this area between the bronze and the zinc coating does not become actually bare of the galvanizing. As stated above, the heat to which the pipe is raised does melt the zinc coating in the zone of the weld, but an oxide is formed, and this oxide takes the place of the galvanized coating, resisting and preventing corrosion along this area. Corrosion tests, which have been made of brazed galvanized pipe, prove this statement.

The technique of brazing galvanized iron with

Tobin Bronze does not differ from the practice heretofore described in several lessons. The bronze flows easily and freely upon the galvanized coating and adheres to it tenaciously.

Galvanized pipe is being increasingly used for drainage and vent pipes of plumbing systems in the larger buildings, because it is much lighter than the cast iron pipe systems, previously used for this purpose. Cast iron pipe presents such great resistance to corrosion that it has been used for these drainage systems in past years almost exclusively. Cast iron pipe is made with what is known as a bell and spigot joint; that is, one end of the pipe is formed into a socket or bell to receive the other end of a pipe which has a slightly raised rim upon it called the spigot end. These two ends are placed together and calked, or packed, with oakum. Over the oakum molten lead is poured which, when hard, forms a joint. It is, of course, obvious that a joint of this kind will stand only limited pressure, but as these pipes are subjected to no pressure at all, except the weight of the water passing through them, there is no likelihood of leakage on this account.

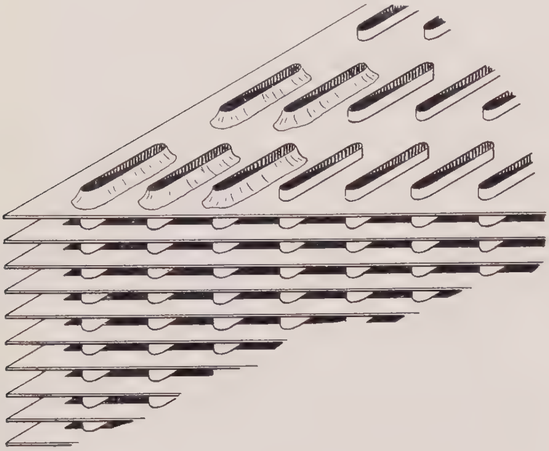


Figure 26—Sketch Showing the Copper Tubes Brazed to the Upper Copper Plate of the Core of a Steam-Air Heating Unit. These Joints were Brazed with Phosphor Copper.

Cast iron pipes are, however, heavy and the weight of such a pipe line is very considerable. This factor alone in constructing tall buildings, like some of the new forty or fifty story skyscrapers, is of material importance, and for that reason, galvanized pipe has been substituted to a large extent for cast iron pipe in the newer and higher buildings. Much of this pipe has been erected with threaded, fitted joints and as explained heretofore, the thread cut in the pipe and fittings cuts through the galvanized coating, and corrosion, beginning at the joint, may shorten the life of the pipe line to a very great extent. It is obvious that brazing applied to such piping systems does away with the threaded joints and provides a leak-proof joint having ample strength for the purpose and being highly resistant to corrosion.

Suggested applications for the brazing of galvanized pipe in buildings are shown in the previous illustrations which are described in detail in the captions. It is true that these brazed joints and the use of galvanized pipe in this manner may not be in accord with the plumbing codes of some of the cities, but when engineers and architects have accepted the brazed joint at its full value, it is believed that these codes will be revised to include such practice. A new process, which proves its merits from an engineering standpoint, must inevitably supersede an old practice when time and experience show that the newer process produces better, more economical and more efficient results.

Welding with Phosphor Copper

An interesting application of the use of a copper alloy having a lower melting point than pure copper plate is shown in Figure 26. This sketch illustrates a tubular heater made up of oval-shaped copper tubes and a series of plates. The upper and lower plates are brazed to the tubing, but the intermediate plates are pressed onto the tubes to hold them in position. Thus a core is made for a heater, through which air is driven by a fan, while steam passes through the tubes. Air is very rapidly heated in this manner, as is well known to users of such heaters in factory buildings and, on a smaller scale, in automobiles. There are so many joints between the tubes and the upper copper plate that, if it were attempted to weld the tubes to the plate by fusion welding, the plate would be warped out of shape and when welding was completed the job would not be a satisfactory one. Welding in such instances requires considerable time, and costs more money.

It was found possible in the construction of some of these heaters to braze the ends of the tubes to the plate with an alloy called phosphor copper, which had a melting point considerably lower than that of the copper plate itself, or the copper of the tubes. It was, therefore, possible to heat the ends of the tubes and the plate to a red heat only, and by applying the phosphor copper, make excellent brazed joints which were accomplished without seriously warping the copper plate or distorting the tubes.

There are, of course, innumerable instances of various articles and equipment, using either pure copper or copper alloys in their manufacture, where brazing can be applied to wonderful advantage. The student will, by this time, realize the adaptability of the brazing process and will apply it to other joints, not mentioned in this lesson, as circumstances may require.

Silver Soldering Nichrome Wire

Many of the electrical heating appliances now made have heating elements, consisting of coils of nichrome wire. This wire has a chemical composition approximately as follows:

Nickel	60 to 66 per cent
Chromium	12 to 22 per cent
Iron	26 to 10 per cent
Manganese	2 per cent

This wire oxidizes very rapidly when brought in contact with a flame, and when this coating of oxide has once formed, it is very difficult to break it up. In the manufacture of appliances using this wire as a heating element, it is usually necessary to join, by some means, the nichrome wire to a terminal post, or to a copper lead-out wire. Because of the difficulty in soldering this wire, the practice has usually been to make a mechanical joint between the nichrome wire and the terminal post, or the copper wire, even though this method does not make as good an electrical joint.

A very simple way to join the nichrome wire to the copper lead-out wire is to silver solder it. This cannot be done in the usual manner, that is, with a torch, as the nichrome wire will, as stated above, oxidize very rapidly, and prevent the silver solder from sticking to the wire. Instead the problem resolves itself into a simple job of dip-soldering.

To do this work, it is necessary to have a small crucible of carbon, graphite, or some other infusible material; some silver solder, some zinc chloride; some borax powder and some boracic acid powder. First of all, mix the borax powder and the boracic acid powder together, using equal parts. Next dissolve in some water as much zinc chloride as the water will dissolve. When this has been done, add sufficient zinc chloride solution to the mixture of borax and boracic acid to form a thin paste.

This mixture produces a flux which should be applied to the end of the wire and permitted to dry. Next melt in the crucible sufficient silver solder to permit the ends of the wire to be dipped deep enough to cover the required surface. Before putting the silver solder in the crucible, however, be sure to have melted in the bottom sufficient borax to form a coating over the silver solder while it is being melted. This coating prevents oxidation from taking place. After the silver solder has been melted, add more borax, if necessary, to the crucible so that the entire surface of the silver solder is covered with a film of melted borax. The heat of the silver solder in the crucible should be kept as nearly as possible just above its actual melting point.

When this has been done, dip the ends of the pieces to be soldered, which have been previously coated with the zinc chloride flux, into the molten silver solder. The pieces should be held momentarily in the silver solder so as to bring the heat of the pieces to be soldered up to the heat of the silver solder. The pieces should then be withdrawn and washed to remove any flux that may adhere to them.

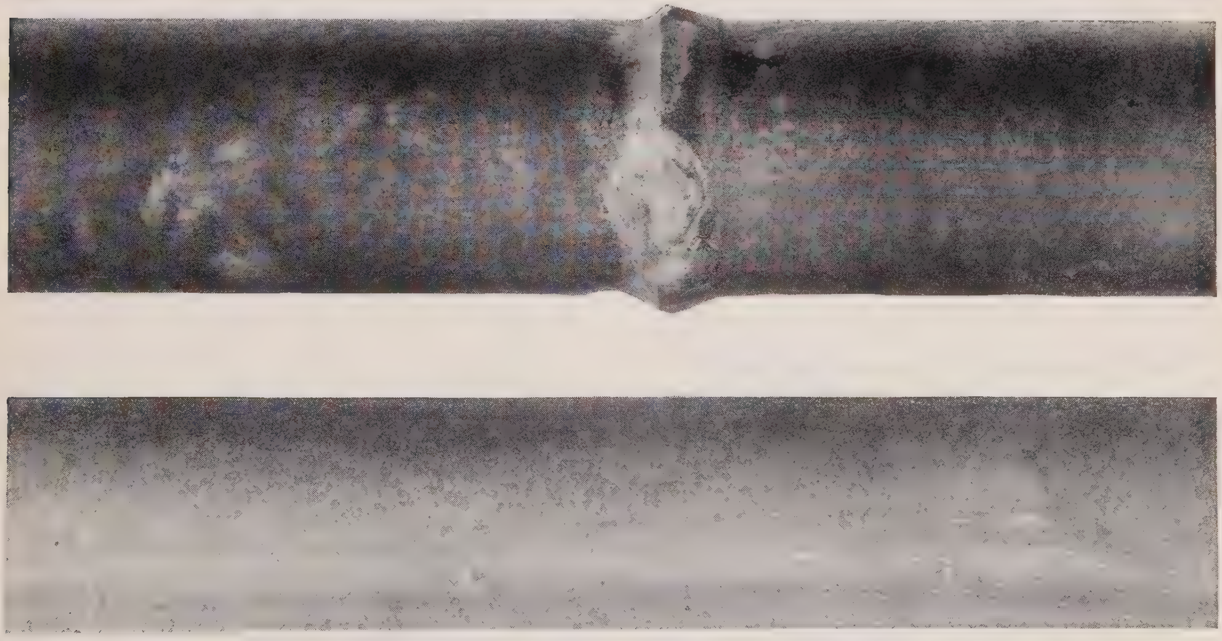


Figure 27—A Joint in Three-Quarter Inch Chase Copper Water Tubing Brazed with Everdur. A Piece of the Original Tube Is Shown at the Bottom of the Illustration to Give a Relative Idea of the Increase in the Diameter of the Tubing Caused by the Test Pressure. The Joint Was Tested to a Cold Water Pressure of 5000 Pounds Per Square Inch. Not the Slightest Sign of Leakage or Cracking Was Indicated and the Only Change Was the Stretching of the Pipe and Joint.

Other Alloys for Low Temperature Brazing

There are other alloys which are used for brazing, some of which have lower melting points than brass and bronze. Phos-Copper, a patented alloy containing about 91% of copper and 9% of phosphorus, has a melting point of about 1300 degrees. Sil-Fos, another patented alloy containing approximately 15% of silver, 80% of copper and 5% of phosphorus, also has a melting point of about 1300 degrees. Easy-Flo is still another patented alloy, consisting of approximately 50% of silver, 15½% of copper, 16½% of zinc and 18% of cadmium and has a very low melting point, about 1175 degrees.

Easy-Flo requires a low melting flux for best results, while Sil-Fos and Phos-Copper are used without flux. Easy-Flo is recommended for brazing steel, stainless steel and copper base alloys. Sil-Fos and Phos-Copper are recommended for the copper base alloys.

Job Sheet No. 15

Brazing Galvanized Pipe
Brazing Copper Pipe

The work in this job sheet consists of brazing together two pieces of two inch galvanized pipe to form a branch similar to the one shown in Figure 21 and brazing together two pieces of copper pipe to form a joint, similar to the one shown in Figure 13.

To do this work the student will need several pieces of two inch galvanized pipe and some three-quarter inch flexible copper pipe. He will also need some one-eighth inch Tobin bronze welding rods and the usual welding outfit, including two welding tips, similar to the No. 3 and No. 1. A can of good brazing flux should also be available.

The first job consists of making the branch out of the two inch galvanized pipe. Using a templet, like the one shown at the top of templet sheet No. 6, cut two pieces of the pipe by means of a cutting assembly, so that the ends make a neat fit. Next insert the No. 3 welding tip in the torch handle, line the two pieces up properly and make a tack weld using Tobin bronze welding rod to hold the pieces in place. After the pieces have been properly tacked, proceed to apply Tobin bronze in the manner described in the previous lessons. In order to protect the galvanized coating of the pipe, however, the heat of the flame should be confined as much as possible to the weld itself.

The student should, as in previous lessons, repeat the exercise until he can produce a neat, sound piece of work.

The next job to be performed is that of brazing together two pieces of flexible three-quarter inch copper water pipe. Two pieces, each about three inches long, should be cut off and the end of one flanged, as shown in Figure 11. In order to flange out the end of this piece of pipe, a flanging tool, such as the one shown in Figure 9 should be used. However, in an emergency, a flanging tool may be made by taking a piece of one inch round steel, heating the end of it with the torch and forging the end of this rod to form a taper.

After the end of the pipe has been flanged out, so that the end of one piece will slip into the end of the other, a distance of about one-eighth of an inch, the pieces should be lined up and held in place, preferably in a vertical position. The welding tip that is in the torch handle should be replaced with a tip the size of a No. 1. Mix some of the brazing flux with just enough water to form a paste and, using a brush, thoroughly coat the space between the two pieces of pipe. When this is done, light the torch and heat the pieces until the flux melts and the copper just comes to a cherry red heat. The end of the one-eighth inch Tobin Bronze rod should then be brought into the flame and allowed to melt and run into the groove until it is filled.

It will be necessary for the student to repeat this exercise until he is able to judge properly the amount of flux, heat and bronze necessary to make a smooth, clean-cut job.

Questions:

1. What is silver solder?
2. What are some of its advantages?
3. Can the welding torch be used advantageously for brazing and silver soldering broken saws?
4. What grade of silver solder should be used in connection with stainless steel?
5. What is a flanging tool, and how is it used by a welder?
6. What are some of the advantages of flexible copper pipe?
7. Why is it better to braze galvanized pipe than to fusion weld it?
8. What are cooling tongs?
9. Why is galvanized pipe replacing cast iron pipe in the construction of buildings?
10. What is the purpose of phosphor copper welding rods?

Lesson No. 16

Welding Aluminum

ALUMINUM is a very important metal to the welder. He will often be asked to repair parts made of it, because many automobile parts are made of this strong, light metal. These include crank cases, transmission housings, manifolds, oil pumps, differential carriers, steering wheel spiders and many smaller parts. Most of these are made of cast aluminum.

Sheet and plate aluminum are used extensively in the manufacture of gasoline tanks for airplanes, for various airplane parts and in many other devices where lightness is an important consideration. In the chemical industries, heavier aluminum plates are used for stills, tanks, kettles and other vessels, where resistance to certain kinds of corrosion is a valuable feature. Aluminum cooking utensils are common in almost every household. In the manufacture of equipment used in making candy, and for the handling of food and similar products on a large scale, aluminum is of great value.

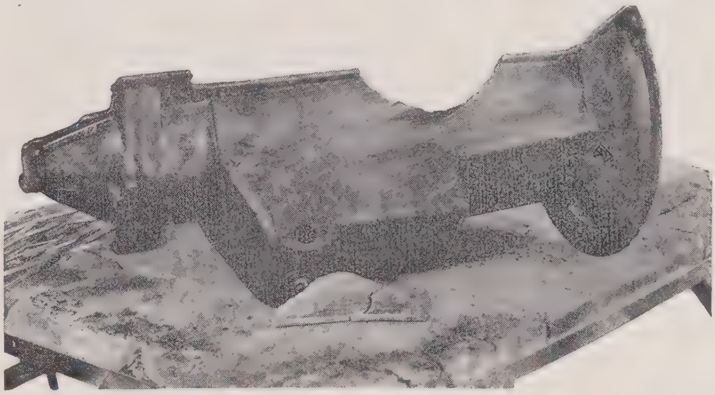


Figure 1—Photograph Showing an Aluminum Crank Case Taken from a Dodge Car of an Old Model. One Side of This Case Was Broken Out in Two Pieces as Indicated. The Pieces Are Shown in the Lower Central Portion of the Photograph.

Aluminum Not a Commercial Metal Until About 1890

Aluminum is a metal which has been known for a good many years. Its discovery is credited to a German chemist, named Frederick Woehler, in 1827, but it did not become a commercial product until the invention by Charles M. Hall, of Oberlin, Ohio, in 1886, of a process for reducing aluminum from bauxite by means of electricity.

Aluminum is the most abundant metal in the earth's crust. It is said that eight per cent of this crust is aluminum. It occurs in almost all clay banks and in the majority of rocks. Despite the fact that it is so abundant, the refining or extracting of aluminum from the clay and rock which contain it is a difficult process. There are three principal rock formations, or minerals, from which aluminum is extracted. These are corundum, cryolite and bauxite.

Bauxite is the more important of the three, because aluminum can be extracted from it at less expense. There are large bauxite beds in Arkansas, Georgia, Alabama and Tennessee. Bauxite is a hydrated oxide of aluminum. The first valuable deposit of bauxite was found in the vicinity of Les Baux in France and its name was thus derived. This mineral formation is shipped to the refining plant for concentration. It contains aluminum oxide but not metallic aluminum, and the concentration necessarily requires the separating of the aluminum oxide from the accompanying clay and metallic impurities, such as iron oxide, sand and titanic acid.

Aluminum oxide, which is called alumina, forms with soda a compound called sodium aluminate, which is soluble in water, while the impurities mentioned above cannot be dissolved. Bauxite is roasted with carbonate of soda, or it is digested with caustic soda in a closed vessel under pressure, to form sodium aluminate.

The sodium aluminate is separated from the impurities by filtration and by washing the residue with hot water. The alumina is afterwards separated from the solution and thoroughly dried, at a temperature of approximately 2000 degrees. It then becomes a white powder, which is very much like fine white sand. This refined aluminum oxide is reduced, by the Hall electric process, to aluminum pigs and ingots. From these ingots, castings and rolled aluminum sheets are made.

Lightness Makes Aluminum Particularly Valuable

Aluminum has some very valuable properties. The property which has made it particularly useful for many purposes is its lightness. The approximate weights of metals and alloys are given in a table on page 119; it will be noted that aluminum is the lightest of these metals, weighing 0.096 pounds per cubic inch. It is one-third as heavy as iron and a little more than one-fourth as heavy as copper. Its heat conductivity is shown on page 16, where the relative conductivity of metals in their order is given as silver, copper, gold, aluminum, wrought iron, cast iron, steel and lead. This table shows that heat will pass through aluminum nearly three times as fast as through iron. The relative malleability of aluminum and other metals is as follows: gold, aluminum, silver, copper, tin, lead, zinc, iron, nickel.

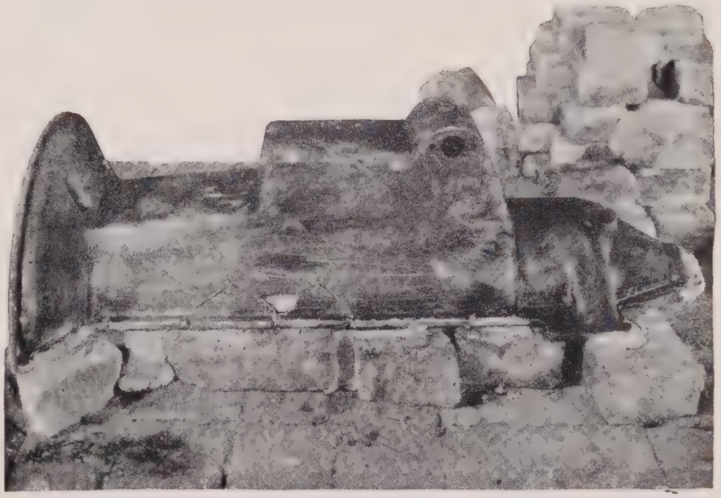


Figure 2—In this Photograph the Crank Case Has Been Set Upon Supporting Bricks with the Broken Parts Inserted in the Break and Tack-Welded. The Metal Backing, or Support Behind the Weld Shows Through the Hole in the Center of the Broken Part. This Was Formed to Fit the Inside of the Casting and Was Held in Its Proper Position with Bricks. Asbestos Cement Was Used Underneath the Casting to Act as Shims to Support the Flange True and Straight. The Asbestos Becomes Hard Very Quickly with the Application of Heat.

Many Castings Are Made of Aluminum Copper Alloys

The melting point of commercial aluminum is given on page 114 as 1175 degrees. The melting point of pure aluminum is usually taken as 1215 degrees and the alloys of aluminum, such as those ordinarily used for crank cases, etc., melt at slightly lower temperatures. Sheet aluminum is usually quite pure, ranging from 98 to 99.75 per cent. The cast aluminum used ordinarily for crank cases, gear cases, etc., is, however, an alloy of aluminum and copper. Many of these castings are made to specification No. 33 of the Society of Automotive Engineers, which is as follows: Aluminum, 88 to 92 per cent; copper, 6 to 8 per cent; zinc, maximum, 2.5 per cent; iron, maximum, 1.5 per cent; silicon, manganese and tin, maximum, 0.75 per cent; other impurities, none. Some of these castings are made to S. A. E. specification No. 30, which is a little higher in aluminum and copper and a little lower in zinc. S. A. E. alloy No. 33 has an ultimate tensile strength of approximately 21,000 pounds per square inch.

Aluminum is always coated with a thin film of aluminum oxide, which prevents further oxidation. This oxide has a melting point of approximately 5400 degrees Fahrenheit. The oxide film increases in thickness as the metal is heated and must be broken down before aluminum can be welded. There are two general methods of breaking down the film, one being a purely mechanical method, using a steel rod and the aluminum welding rod itself and called "puddling," and the other being the use of flux, which dissolves the oxide.

Molten Aluminum Oxidizes Rapidly

Aluminum combines with oxygen very rapidly when melted, and for this reason, great care must be taken to avoid an oxidizing flame. Aluminum will not absorb carbon when in a molten condition, but even so, it is much better practice to use a neutral flame than the carbonizing flame recommended by many welders. The excess of acetylene in the carbonizing flame makes a smoky flame which will smoke or cloud up the surface of aluminum to a greater extent than a neutral flame where more complete combustion is obtained.

Methods of Casting Aluminum

Aluminum castings are generally made by one of three processes. The first of these is the casting of the aluminum in ordinary sand molds, using patterns with gates and risers to compensate for crystallization shrinkage. The second method is the use of permanent molds made of cast iron and using gates and risers in similar manner to sand castings. The third method is the forcing of the molten metal into a mold made like a die from iron or steel, the metal being under high pressure. By this method it solidifies quickly, but without the compensation for crystallization shrinkage which occurs in the other two methods. Pressure die castings are used particularly for parts where a smooth outside shell is important and where high tensile strength is required.

Crank cases, oil pumps, manifolds, transmission cases and spiders for steering wheels are ordinarily made of sand castings. Vacuum sweeper parts, pistons, hub caps, bearing caps, and other such parts, are usually made by the second method, using metal molds. Small parts, like those used upon phonographs, vending machines, magnetos, vacuum sweepers, typewriters, throttle control parts, etc., are often made by the die cast method. Many of these parts are made from alloys of aluminum containing approximately ninety-two per cent of aluminum and eight per cent of copper.

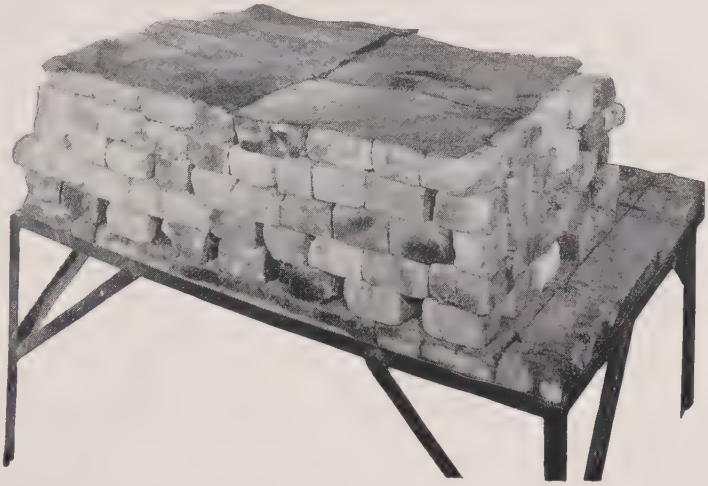


Figure 3—The Completed Preheating Furnace, with the Casting Therein, is Shown in This Photograph, Covered with a Sheet Iron Top. This is the Most Convenient Form of Furnace in Which to Heat a Casting of This Kind and, While a Little More Trouble, Insures Even Expansion of the Casting.

The Metal in Light Sections Is Stronger Than That in Heavier Ones

In aluminum castings made of this alloy, the strength and elongation decrease as the section of the metal increases. For instance, in certain tests mentioned in Kent's Mechanical Engineers' handbook, a sand cast test bar one-quarter inch in diameter showed a tensile strength of 25,000 pounds per square inch and elongation of three per cent. When the diameter of the cast bar was increased to one and one-half inches, the strength was decreased to 14,000 pounds and the elongation to one per cent. It is, therefore, to be expected that the heavier sections of a casting will have less strength per unit of area than the lighter sections.

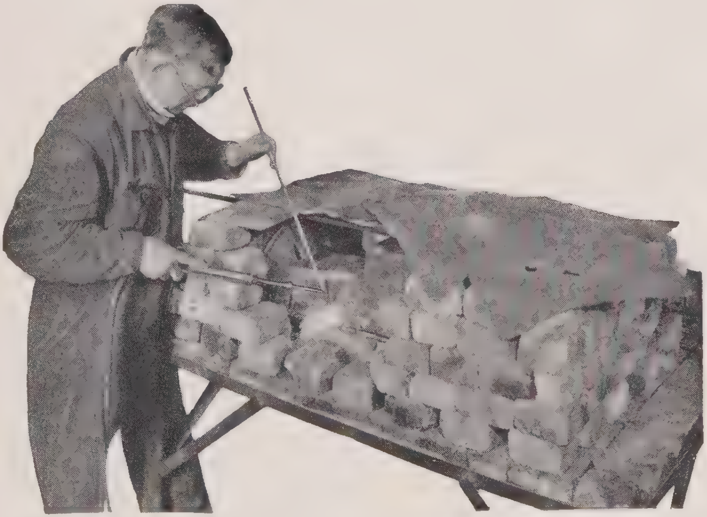


Figure 4—After the Casting Has Been Heated to Approximately Five Hundred Degrees a Few Bricks Are Torn Away from the Side of the Wall Adjacent the Break and the Weld Begun with the Torch. As the Casting Lies Within the Furnace Completely Covered, Except for This Small Portion, It Remains Hot and Evenly Expanded Throughout.

Aluminum Should Solidify Quickly

Another statement made in Kent's handbook is of interest to welders; this refers to the quickness of cooling aluminum from the molten state. The more quickly aluminum alloys solidify, the smaller will be the grain size and the higher the tensile strength and the elongation. An instance is given of the eight per cent copper alloy when cast in sand in a one-half inch test bar. This bar had a tensile strength of about 20,000 pounds per square inch with an elongation of one and one-half per cent. When a similar casting was made in a metal mold, the strength increased to 31,000 pounds per square inch and the elongation as high as six per cent. It is safe to say, therefore, that the quicker the welder allows the molten aluminum to solidify, the stronger the weld will be. This does not mean, however, that the entire casting must be exposed to cold drafts or to the chill of a cold room and that it need not be protected, or cooled slowly. The casting after the metal has solidified should be carefully protected as hereafter described, and allowed to cool slowly.

Welding Cast Aluminum

The welding of sheet and cast aluminum are distinctly different processes which must be dealt with separately, because of the great difference in the technique of welding. Sheet aluminum is used, as stated before, to a very great extent in the manufacture of gasoline and oil tanks used for airplanes. The average welder, however, will not encounter these tanks in a welding shop until the airplane becomes universally used. For this reason, sheet aluminum welding is dealt with separately and the welding of cast aluminum is taken up first in this lesson. For the welding of cast aluminum, the oxy-acetylene flame is almost always used. While hydrogen and some of the oil gases are excellent for the welding of sheet aluminum, these gases do not produce a flame having sufficient heat to weld large aluminum castings.

The average casting which the job shop will be obliged to weld is, in all probability a crank or gear case, from an automobile. Aluminum crank and gear cases are, of course, becoming less common with the sale of the newer cars and the scrapping of the older ones, but for a considerable time old cars will be brought into welding shops with broken aluminum cases for repair. The welder's education would not be complete without a thorough knowledge of how this work should be accomplished. Furthermore, a broken aluminum crank or gear case is a fair example of any other cast aluminum repair, as for instance, airplane engine castings; the principles set forth for a repair of this kind are similar to others, whether the aluminum casting is used upon an automobile, an airplane, or for the housing of some entirely different piece of machinery.

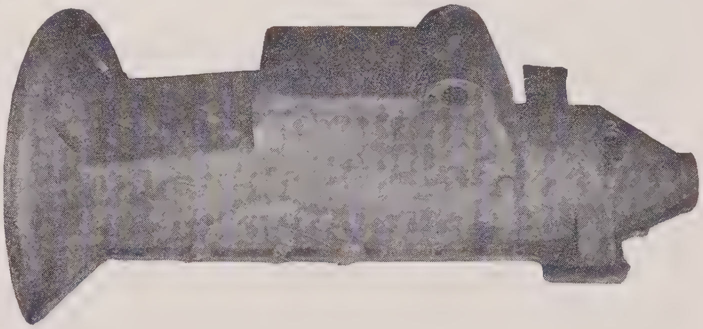


Figure 5—The Completed Weld Is Indicated in This Illustration. This Weld Was Made by the Flux Method and Was Not Smoothed with the Paddle, Which Is Common Practice When the Weld Is a Puddle Weld Made Without Flux.

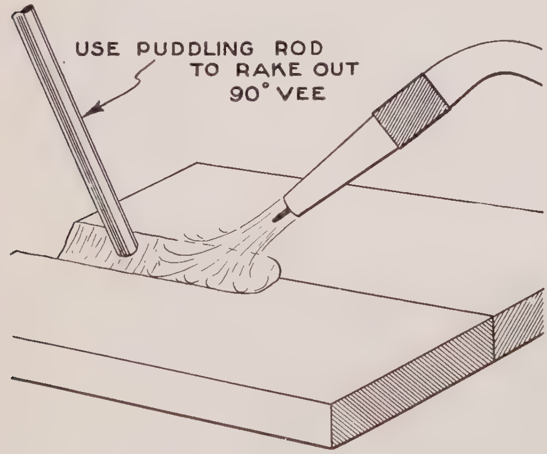


Figure 6—Sketch Showing the Puddling Rod Used to Rake Out the Cracked Joint to a Vee of Ninety Degrees. One Side of the Vee may be Raked Out First and then the Opposite Side. The Metal Must be Heated with the Torch, Before Raking in this Manner, and about Two Inches of the Crack Should be Raked Out before Welding is Started. Thinner Sections do not Require this Treatment.

Preheating Essential For the Beginner

While it is entirely possible to make some welds in lugs, or in other parts of a crank case, which are free to expand and contract, without preheating, in most instances it is necessary entirely to preheat these castings. This can be accomplished to good advantage by bricking in the casting to make a fire-brick furnace and using charcoal as a fuel. There are a number of shops where city gas, without compressed air, is used as a preheating fuel with brick furnaces and several burners, made from pieces of pipe, stuck through holes between the bricks. City gas can be used in this manner if desired. Some welding shops are equipped with large preheating stoves, consisting of a number of city gas burners set close to each other and connected so that they can be separately shut off.

The means of preheating is largely a matter of preference with the welder and is dependent to a considerable extent upon the facilities at hand. For the purpose of this lesson, an old Dodge crank case is illustrated, and the various steps in the repair are described. This crank case with pieces broken out of the side of the casting, is illustrated in Figure 1.

Some skilled welders would repair this casting without preheating, but to undertake this job, with such limitations, requires a thorough knowledge of the behavior of aluminum when heated and the skill of an experienced man in order to avoid setting up strains in the casting. It is, therefore, far better practice to preheat it.

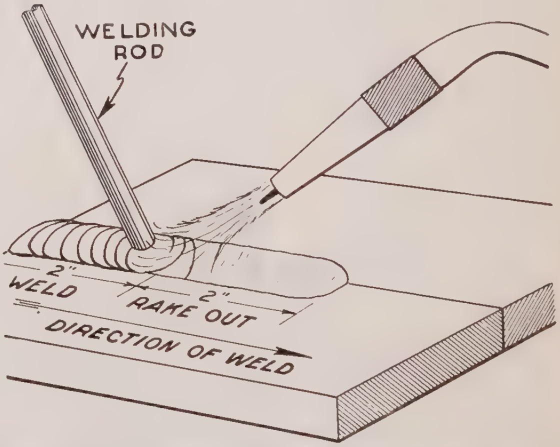


Figure 7—The Advanced Flame Method from Left to Right may be Used for Welding Aluminum if Desired. The Movement of the Torch, however, is Optional with the Welder. The Luminous Cone of Flame Should not be Held Too Close to the Metal. The Rod will Not Melt in the Puddle when Welding Aluminum, as It will with Other Metals and the Torch must be so Held that Both the Rod and the Edges of the Crack will be Melted Simultaneously. About Two Inches of the Seam is Welded after having been Raked Out and this Process Repeated Until the Entire Seam has been Welded.

The Casting Should be Thoroughly Cleaned

The first operation in beginning this repair is to clean thoroughly the grease and oil from the casting. This can be done with a wire brush and gasoline. The entire vicinity of the break, both on the inside and on the outside of the casting and the broken pieces themselves, should be very carefully cleaned in this manner until bright. It is not necessary to vee the edges of either the casting or the parts broken out, but it is good practice to back-up the break, either with sheet copper or sheet steel, so that there will be a support for the puddle of molten metal. A skilled welder often will not take the time required to back-up a weld in this manner, relying wholly upon his skill to cool the metal at the right moment to prevent it from becoming too hot and collapsing. A beginner, however, should support or back-up the weld rather than attempt to do the job without backing.

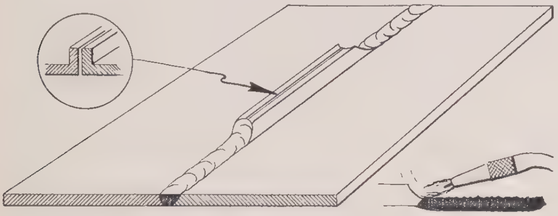


Figure 8—This Figure Illustrates the Flange Method of Welding a Seam in Light Sheet Aluminum. Sheets Less than One-sixteenth Inch in Thickness Should be Flanged in this Manner. The Torch Must be Held at a Very Flat Angle as Indicated in the Small Figure to the Right.

If the Casting is Not Well Supported It is Likely to Warp

A very important detail of the repair of a casting of this kind is the proper support of the casting underneath the flanges in such manner that it will not sag or warp when heated. Particular care should be taken to see that the casting is properly supported and that the parts are in proper alignment before the preheating furnace is constructed.

In Figure 2 the casting is shown supported by fire-brick set upon a fire-brick welding table and securely held in position with a paste or putty of asbestos, shredded finely and mixed with water. This asbestos putty bakes hard with the heat of the preheating fire and effectually supports the casting. There are other compounds upon the market, including a carbon putty, which can be used for this purpose. In Figure 2, the pieces which were broken out of the casting are shown carefully fitted into place, the center piece having been left off to show the backing which, in this instance, was a piece of sheet steel formed to the contour of the inside of the casting. These pieces were tack-welded on the inside before the casting was set up in position.

When the casting has been set securely in place, fire-brick is built up in a wall around the entire casting, leaving holes in the bottom row of bricks for draft and placing a sheet iron cover over the furnace, as illustrated in Figure 3. This method of preheating does not differ from the methods heretofore described, except that greater care must be taken in the amount of charcoal placed in a furnace of this kind when aluminum castings are to be preheated. There is no danger of overheating a cast iron casting with charcoal, but if too much is placed in the furnace, the fire is likely to overheat an aluminum casting and cause it to collapse.

Too Much Heat Will Ruin the Casting

Aluminum is very weak when hot and a casting should not be heated to more than 500 degrees Fahrenheit. This temperature is just enough to char a white pine stick, or sawdust, and a little more than enough to melt soft solder. It is always desirable to place the charcoal around the walls of the furnace, so that it will not touch the aluminum casting. The amount required is, of course, dependent upon the casting, but for a job of this kind five or six shovels-full should be enough. The fire may be controlled by proper manipulation of the draft holes. It should be kept even and should not burn brighter on one side of the furnace than on the other. Any one of the draft holes may be easily blocked off with a little asbestos paper, or some sand, and if the fire gets too hot, all of them should be blocked off.

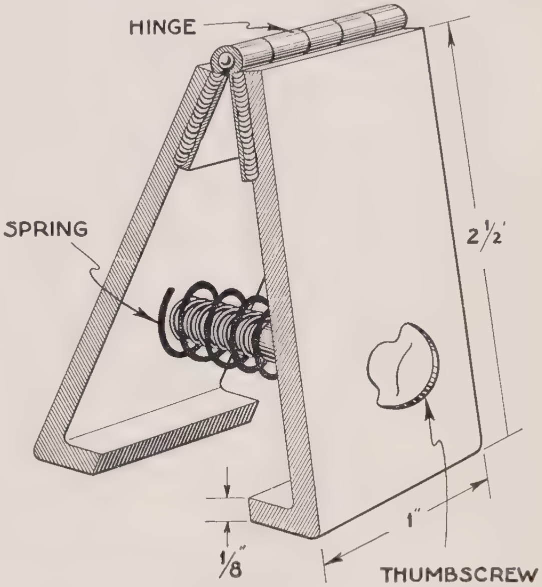


Figure 9—A Very Convenient Clamp is Illustrated in This Sketch. Such Clamps are Used to Hold the Flanges of the Seam Together Until They are Tack Welded. The Spring within the Clamp Opens it Quickly when the Thumb Screw is Released.

About one-half hour of preheating is sufficient as a rule and during this time, the welder should pay close attention to the fire. With an iron casting he can let the fire take care of itself to a large extent, but an aluminum casting requires much closer watching. If the casting becomes too hot, it may be found in the furnace so badly melted that it cannot be used for any purpose.

The degree of heat can be easily controlled and care will prevent damage to the casting.

Welding Rods

It is just as essential to use a correct welding rod in connection with aluminum, as with any other metal, and often this subject is given the least consideration by welders. Many welding shops have made their own aluminum rods by melting up old gear cases and casting the rods in makeshift molds of some kind. Other shops have purchased cast aluminum welding rods which have been furnished, from time to time, of various alloys. Some other shops have used pure aluminum welding rods for welding gear cases.

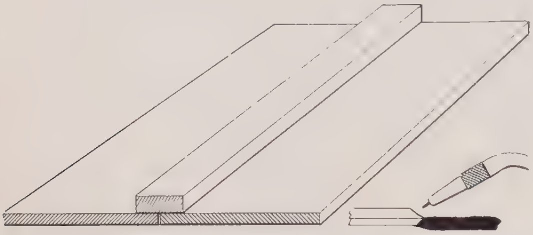


Figure 10—A Method of Welding Aluminum Sheet Used by a Large Automobile Body Manufacturer. The Strip Over the Seam Has Been Trimmed from a Sheet and Coated with Flux. It Is Laid Over the Joint, Securely Clamped in Place and Fused with the Torch, Together with the Edges of the Sheet, to Make the Joint.

Among the peculiar characteristics of aluminum is its weakness, or what is commonly known as hot-shortness, just below the temperature at which the casting begins to melt. There is another condition which must be taken into account and that is the fact that aluminum shrinks to a very considerable extent as the molten metal solidifies. This contraction is two and one-half times greater than steel and must be taken into account, or the metal will crack adjacent the weld as it cools.

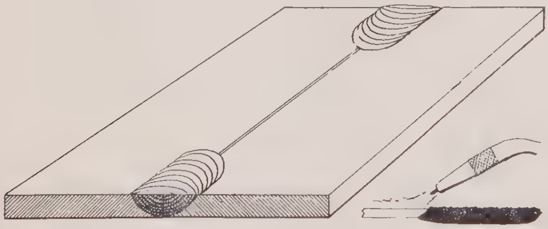


Figure 11—Aluminum Sheets Less Than Three-Sixteenths of An Inch Thick Need Not Be Bevelled. The Plates Are Butted Together, as Shown in This Figure, Tack Welded at Intervals of One Inch, and Then Welded as Heretofore Described. The Edges of the Sheets and the Welding Rods Must Be Well Coated with Flux, to Insure Breaking Down the Oxide Film Over the Weld Metal and the Sheets.

Aluminum, Silicon Alloy Welding Rods

A paper was read before the Gas Products Association at Grand Beach, Michigan, in June, 1929, which was written by Mr. W. A. Dunlap of the Metallurgical Division of the Research Bureau of the Aluminum Company of America. This paper gave some very interesting facts and figures, some of which are quoted, with reference to the most recent developments in aluminum welding. One of these is the recommendation of an aluminum alloy welding rod, consisting of ninety-five per cent aluminum and five per cent silicon, for use with copper alloy castings and for pure aluminum where the parts are tightly held in a jig, or where shrinkage of the metal would cause difficulty. The aluminum, silicon alloy, of which these rods are made, is not hot-short and the shrinkage during solidification is very small. Furthermore, the melting point of these rods is lower than aluminum and the aluminum casting will cool below the point of solidification before the weld metal, made by melting in these rods, will solidify. The result is a transfer of the shrinkage strains to the weld metal while it is still plastic.

These silicon alloy welding rods can be secured from local dealers in welding rods, or, if they are not carried in stock, directly from the Aluminum Company of America. Furthermore, the silicon alloy resists corrosion and produces a strong weld, so that welders need have no hesitation in using it for welding any of the usual alloys from which castings are made. The silicon alloy is not a cast rod, but in appearance closely resembles the pure aluminum welding rod, usually supplied for aluminum welding.

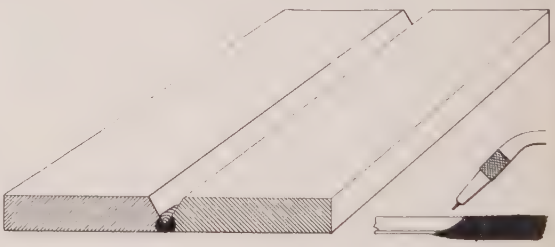


Figure 12—Metal Three-sixteenths of an Inch and Heavier Should Be Bevelled by Grinding the Edges to an Included Angle of Ninety Degrees. This Practice Is Generally Similar to the Preparation of the Edges for Steel and Cast Iron.

Aluminum silicon alloy rods are furnished by the Aluminum Company of America in diameters of one-eighth, three-sixteenths and one-quarter inches in coils. The pure aluminum rods can be purchased in rod form in any diameter from one-eighth inches up. In coils, pure aluminum wire can be obtained from No. 20 gauge, or a diameter of .032 inches up to one-quarter inch.

Methods of Welding

There are two general methods of welding aluminum castings. One of these is commonly called the flux method; the other the puddling method. As stated heretofore in this lesson, aluminum is always covered with a coating of aluminum oxide, which covers the molten puddle of aluminum to such an extent that it must be broken up before the puddle will flow or join with other hot metal. Breaking up this aluminum film can be accomplished with aluminum flux by dissolving it, or mechanically by stirring the puddle with the welding rod, or a special puddling rod. Some welders prefer to use both of these methods at the same time, by applying flux to the casting and stirring the puddle of molten aluminum constantly to keep the oxide broken up with the welding rod.

Flux and Puddle Methods Compared

The flux method of welding aluminum has the advantage that the flux actually dissolves the oxide and floats it to the surface, so that the oxide is not included in the weld metal as it often is when the puddle method is used and the flux is broken up mechanically with a rod. Of course, in puddle welding the welder eliminates all of the oxide which he can, but it is obvious that he cannot rake out all of it from the weld and some of it must be included in the molten metal as it solidifies. Inclusions of oxide in the weld metal, of course, weaken the weld and this disadvantage is inherent with all puddled aluminum welds.

PUDDLING ROD

On the other hand, the flux which is used for welding aluminum, to be effective, must be corrosive and for this reason, it is essential that it be completely removed after the weld has been made. This can be done by first washing the weld in hot water, then in a hot five per cent solution of either nitric or sulphuric acid and then again in clean hot water to remove all traces of acid. Washing with hot water and scrubbing alone will not always remove every trace of flux, which is essential. This is the disadvantage in welding aluminum castings with flux.

In the first place to make the flux effective, castings must be very thoroughly cleaned to eliminate oil and grease and after they have been welded they must be cleaned as above described to eliminate the flux. It is for these reasons that some welders prefer to use the puddling method rather than the flux method. Another reason often given is that with the puddling method the weld can be finished smoother by scraping it off with the paddle when the metal is just plastic.

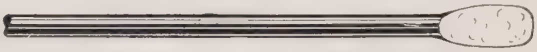
In all probability, it is largely a matter of becoming accustomed to the technique of either method for it is well known that many excellent aluminum jobs are accomplished both with and without flux.

The Puddle Welding Method

In puddle welding aluminum, it is customary to use one or two special tools made from one-quarter inch steel welding rods. One of these is a rod having the end flattened, often called a paddle, and the other just a round, straight steel welding rod used as a puddling rod. The practice of various welders in this respect, of course, differs, depending upon individual preferences. Some welders will heat the casting until the metal becomes plastic, when they will use the paddle to smooth over, or form, the soft metal until a union is made between the two edges of the casting, and the metal takes the shape which they desire. This is not real welding and, while some successful jobs have been done in this way, the strength of such a weld is not what it should be, nor anything like that attained by good fusion welding. It is just as necessary to fuse or melt aluminum, when welding it, as any other metal, and if it is not thoroughly melted, the job will not be as strong as it can be made.

In making a weld in an aluminum casting by the puddle method, the flame is applied to the metal, taking care not to bring the luminous cone too close and the edges of the casting are melted forming a puddle. This puddle should not be too large or it will become unwieldy and flow away. It will be remembered in the description of the job shown in the illustrations that a piece of sheet steel was used underneath the weld to support it. This method assists materially in preventing the collapse of the weld and enables the use of a slightly larger puddle.

As soon as the puddle is formed, the puddling rod should be thrust into it and as much of the oxide as possible raked off the surface and scraped off the edges of the casting. When the surface of the puddle has been cleared in this manner, a thin film of oxide will immediately form on top of the molten metal. The welding rod should be thrust through this film and the heat maintained so that the molten metal of the rod will join with the metal of the puddle under the film of oxide.


PADDLE

Constant Stirring is Necessary

The welding rod should be stirred in the puddle constantly to keep the oxide broken up as much as possible and to be sure that the molten edges of the casting and the added metal fuse together. From time to time it may be necessary to remove the aluminum welding rod and to use the puddling rod to break down some difficult oxide formation, or to bring the edges of the casting into complete union with the weld metal.

The manipulation of the welding and puddling rods must be learned by the welder; this can only be done by practice. The first few welds which he makes are not likely to be successful and he must continue practice welding until he learns how to handle the rods and the torch to best advantage. The moment either the welding or puddling rods are removed from the puddle, the torch should be slightly withdrawn to let the metal solidify. When the torch is again applied to the puddle to continue the weld along the seam, either the welding rod or the puddling rod should immediately be used in conjunction with it to eliminate the crust of oxide upon the molten metal and to maintain thorough fusion between the molten edges of the casting and the added weld metal. It is necessary to synchronize carefully and accurately these movements of torch and rod to produce the best results.

The puddling rod must not be allowed to become any hotter than can be avoided and if it does become red hot and collect a coating of oxide at the end, part of it can be melted away with the torch, away from the weld, and the clean end used again. Particles of steel from the rod should not be allowed to get into the puddle. They will remain in the aluminum unmelted as inclusions of foreign material which will seriously weaken the weld. From time to time the rod can be knocked on the side of the welding table to remove aluminum oxide that has collected upon it.

When Heated, Aluminum Does Not Show Color

The important part of the flame manipulation is to prevent overheating the casting so that it will collapse before the heat can be withdrawn, and the metal allowed to solidify. It should be remembered that aluminum does not show color, when heated, and there is, therefore, no indication by its appearance that the metal is too hot. This can only be detected by the feel of the metal with the welding rod. If it becomes too soft the torch flame must be withdrawn momentarily until it solidifies.

After two inches of the crack are welded in this manner, a second two inches should be welded in like manner. This method of operation should continue until the entire crack has been completed. In Figure 4 the Dodge crank case is shown after a few of the bricks of the wall had been pulled away when the casting had been preheated hot enough to be welded. The operator is shown with the torch and the welding rod beginning a short section of weld. The photograph was taken in this manner, so that as much of the weld as possible would show but the position of the torch and the rod are not as when the weld was actually started.

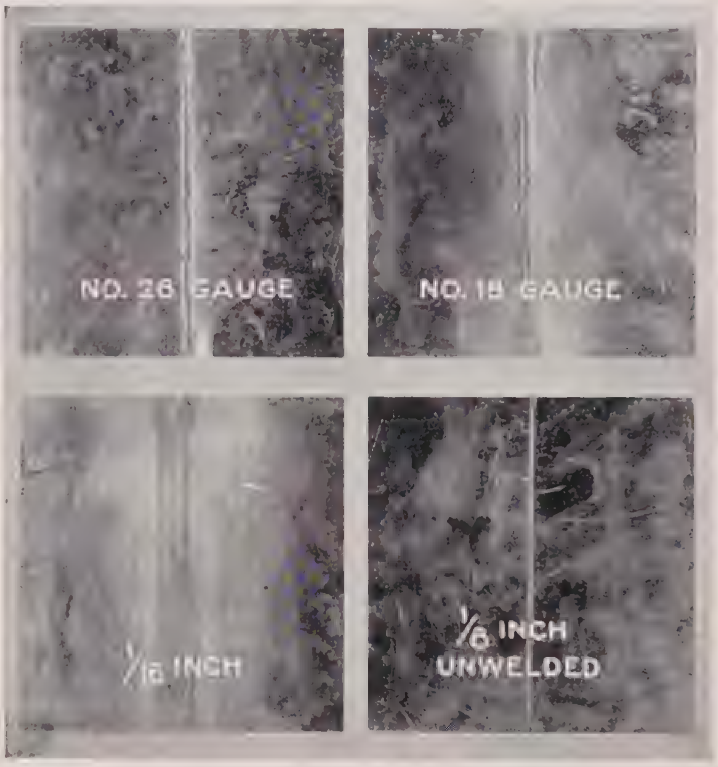


Figure 13—These Photographs Show Seams Welded in Sheet Aluminum of Thicknesses Marked on the Photographs, Using Oxygen and Hydrogen with the Torch. The Seam in the Lower Right Hand Photograph Is Not Welded, but Shows the Edges Straight and Square Placed Together for a Simple Butt Weld.

Welding Procedure

The weld should start at the middle of the break at the inside of the casting and should proceed, in two inch sections, from this point around to the outside edge of the casting. Welding should then begin again at the center and be carried on to the opposite outside edge in similar manner. The internal crack, and the hole shown in the center, where the backing plate appears through the cracked portion, should be filled in solidly with melted welding rods and fused to the broken parts. When a two inch section of weld is completed, the paddle may be used, if desired, to smooth the weld until it is even with the surface and conforms to the contour of the casting.

In Figure 5 the completed repair is shown after it had been removed from the furnace. It is always desirable, after a job of this kind has been welded, to reheat the casting to an even heat, pack the furnace tightly closed, and allow the casting to cool down very slowly. This will compensate for any inequalities in expansion which may have occurred and allow the casting to contract slowly and evenly.

Flux Welding Aluminum Castings

The manufacture of fluxes for use with aluminum requires considerable chemical and metallurgical knowledge of the metal. Good flux can only be made in a plant having sufficient chemical apparatus to analyze and mix the chemicals accurately, under the supervision of chemical engineers. The average welder should never attempt to mix his own flux. There are many good aluminum fluxes upon the market which fulfill all ordinary requirements. Some of these are made especially for cast aluminum and others of a more expensive formula for sheet aluminum.

The flux should be mixed with water and applied after the casting has been cleaned with gasoline, hot water and a brush. The rod should be dipped into the flux to coat it. A suitable flux container is valuable for this purpose, a convenient one being described in the paragraphs on the welding of sheet aluminum. All sheet aluminum is welded with flux, and a container is even more necessary for this class of work.

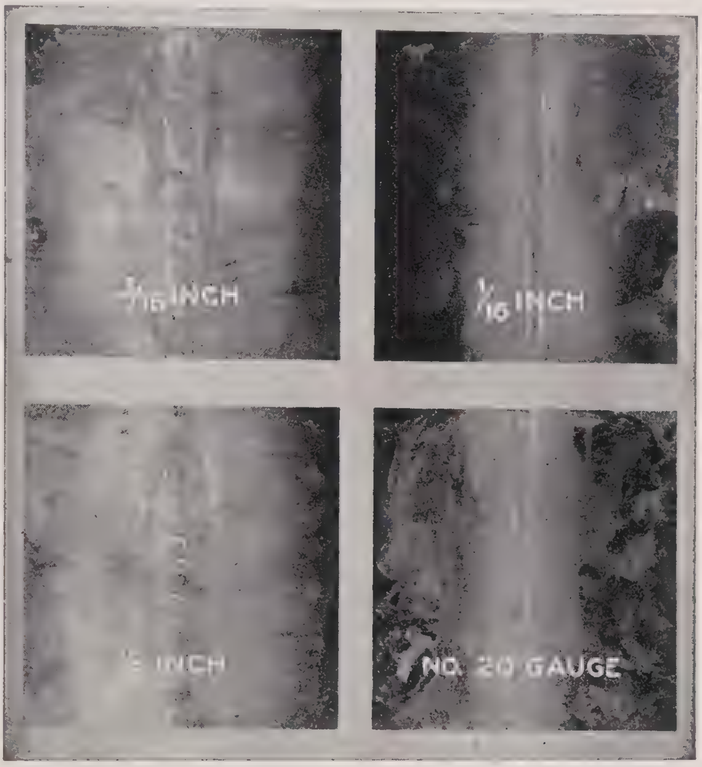


Figure 14—Photograph Illustrating Aluminum Sheets of Various Thicknesses Welded with Oxygen and Acetylene. Many Welders Will Not Use Hydrogen for Welding Aluminum Sheets Thicker Than One-sixteenth Inch.

For flux welding aluminum castings, the methods of preparation and preheating do not differ from those described for the puddle system. The castings must be clean along the line to be welded and thoroughly coated with flux. About two inches of the crack, in the heavier sections of metal, should be heated with the torch and veed out to a ninety degree vee with the puddling rod. This operation is illustrated in Figure 6. The rod may be used to scrape away, or vee, one side of the break and then the other side. Veeing, in this manner, is only necessary when the thickness of the metal is three-sixteenths inches, or more, and when the welder is uncertain whether he can penetrate clear to the bottom of the casting without raking out the crack.

The Movements of the Torch and the Rod Are Optional

After two inches of the crack has been raked out to the ninety degree vee, the weld is started at the beginning of the vee and the flux coated rod used to complete it. A stirring motion of the rod is beneficial and will assure fusion of the edges of the casting and the weld metal. The rod may be held in relation to the torch, as illustrated in Figure 7, using the advanced flame method from left to right, as described on page 82 in connection with the welding of steel. Some aluminum welders prefer this method; others believe that some of the other torch and rod movements, described under steel welding, are preferable. The movement of the torch in aluminum welding is optional with the welder. He may find that he can do better work with one movement than another. With the experience which he has already had in these lessons, it is unnecessary to say more in this connection.

The flux method of welding aluminum will ordinarily leave a ripple aluminum weld which, in many instances, may be left more or less rough, or built up a little higher than the surface of the casting for reinforcing purposes. The weld shown in the crank case, illustrated in Figure 5, was a flux weld made in this manner. When flux is used, it is essential, however, that it be entirely removed from the casting, as has been heretofore described. Otherwise, corrosion may set in which will eventually cause trouble.

Welding Sheet Aluminum

Sheet aluminum is always welded with flux. It is not heavy enough to puddle and the torch must be moved over a seam between thin sheets very rapidly, in order not to melt holes through the metal. Welding sheet aluminum demands skill, and the first attempt of the welder, even though he is skilful in welding steel and cast iron, will probably result in quite unsatisfactory work. It is only by constant practice that he can become skilled enough to make a really good weld. He need not be discouraged, however, because there is in reality nothing very difficult about the technique of welding sheet aluminum. In the very thin sections no welding rod is used and successful welding becomes largely a matter of correct preparation of the sheet, suitable jigs and quick, skilful handling of the torch.

Flanging the Edges of Thin Sheet Aluminum

Sheet aluminum less than one-sixteenth inch in thickness should be flanged at the edges, as shown in Figure 8. Some welders will flange one-sixteenth inch thick plate; others prefer to butt the two edges together and weld this thickness, as indicated in Figure 11. This is largely a matter of preference, but flanging one-sixteenth inch sheet would be better practice if economical methods of flanging are available. Sheets thinner than one-sixteenth inch should always be flanged.

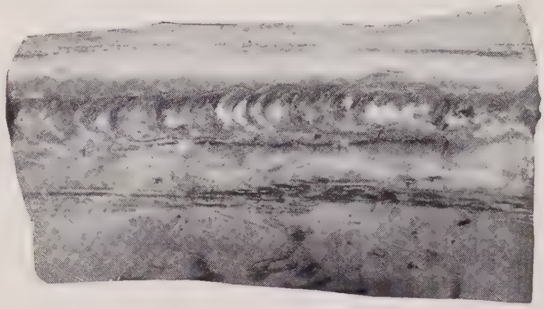


Figure 15—Photograph of a Good Aluminum Weld, in Three-sixteenths Inch Aluminum Plate, Made After the Edges Had Been Bevelled, as Shown in Figure 12. This Plate Has Been Bent to Show the Ductility of the Weld. This Weld Was Made with Oxygen and Acetylene.

Flanging of aluminum sheet is accomplished in a bending brake and the flanges are made as nearly one-sixteenth of an inch in height as possible. It is not always possible to bend these flanges exactly one-sixteenth; if they are not more than one-eighth inch in height, they can be fused down to make a satisfactory weld. The accuracy and the tightness of the bending brake will usually determine the height of the flange.

In welding a flanged seam between thin sheets of aluminum, clips or clamps, like that shown in Figure 9, are used four or five inches apart along the length of the seam. These clamps hold the flanged edges together until tack welds can be made at intervals of about one inch. As the tack welds are made, the clamps are removed. Welding is then started at one end of the seam and progresses very rapidly to the opposite end. The torch should be held at a very flat angle, as indicated in the small sketch to the right of Figure 8, to prevent melting holes through the thin sheets. It is necessary, of course, to use a very small torch, producing a very small luminous cone of flame, if acetylene is used. If hydrogen is used, the flame, of course, must be larger, because of the lower heat.

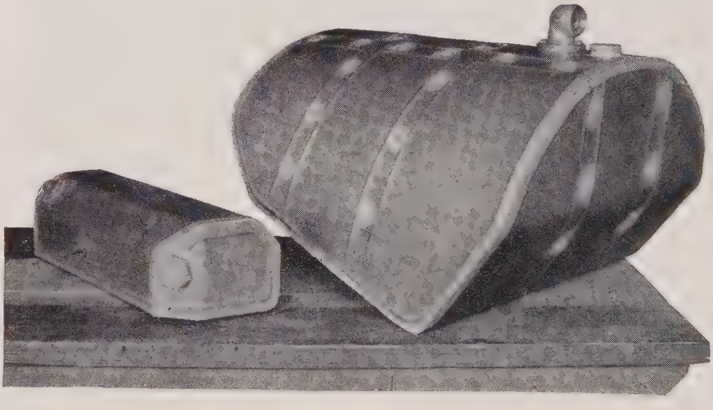


Figure 16—Photograph of Aluminum Gasoline and Oil Tanks. The Large Tank to the Right Is a Gasoline Tank for an Airplane, and the Tank to the Left an Oil Tank, Which Is Located Immediately Forward of the Gasoline Tank. These Tanks Are Attached to the Top Cowling of the Fuselage Immediately Forward of the Cockpit.

After the sheets have been properly flanged the next operation is to clean thoroughly the edges and coat them with flux. Coating is done by dipping a brush in the flux container and applying the flux along the seam, being careful to thoroughly coat the bottom, the top and the inside surfaces between the flanges, as well as the surface on each side of the flanges for the width of the weld. Careful coating of the flux is particularly important; otherwise the metal will not run together. The sheets of aluminum should not be supported under the seam, as one object of the welder is to force some of the metal, fused from the flanges, downward to increase the thickness of the seam under the weld, as well as on the upper surface.

For thin sheet aluminum the inclination of the torch with relation to the sheets should be at a very flat angle, as shown in Figure 8. As the thickness increases, the angle of the torch may become more obtuse until, with heavier sheets, it is inclined about forty-five degrees, as is the case in the welding of other metals. The luminous cone of flame, however, should not be brought too close to the metal. Experience will show how close this should be and the thickness of the sheet will govern the distance to a large extent.

Welding with Flux Coated Strips

Another method which has been used successfully by one of the large automobile body manufacturers is illustrated in Figure 10. This method consists in cutting strips from the sheet, the length of welding rods, and dipping these strips in acid thoroughly to clean them. The strips are then dipped in flux and dried, so that they are flux coated. These flux coated strips are placed over the seam between two thin aluminum sheets, as shown in Figure 10, after the sheets have been thoroughly cleaned and coated with flux. The torch is then used to melt down the strips to make the seam, just as the flanges are melted down in Figure 8. Of course, it is necessary to hold the strips in close contact with the sheets, and to hold the edges of the sheets tightly together. It is said that this method enables a beginner to weld aluminum sheets with very little practice and to make greater speed than can be done by other methods.

Gases Used for Aluminum Welding

For welding light sheet aluminum, hydrogen produces a very satisfactory flame, when burned with oxygen, with a well designed torch. Hydrogen, however, is becoming more and more difficult to secure, because of the abandonment of the electrolytic process for the manufacture of oxygen and the substitution of liquid air machinery for this purpose. There are still some electrolytic oxygen-hydrogen producing plants, which produce hydrogen particularly for use in connection with the hardening of fats and oils and this source of supply is available in some cities.

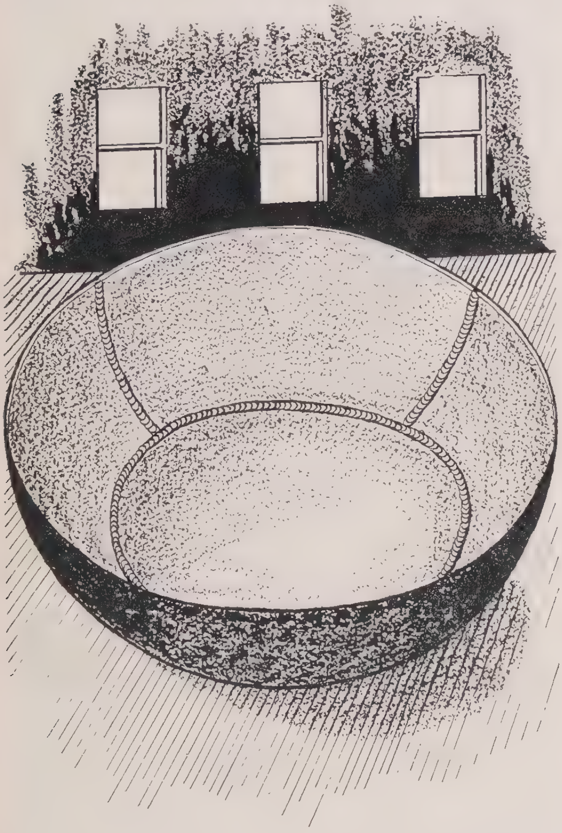


Figure 17—Welding a 1,900 Gallon Capacity Rosin Still, Made of Three-quarter Inch Cold Rolled Aluminum Plates. This Sketch Illustrates the Bottom with the First Row of Plates Welded in Place.

On the other hand, excellent gases for the welding of sheet aluminum are being distributed to a constantly increasing extent by the oil companies. Some of these gases, compressed in cylinders in the form of a liquid, and sold under trade-names, are commercial propane. This gas, when burned with oxygen with a suitable torch, makes an excellent flame for the welding of thin sheet aluminum, and can be used in place of hydrogen if desired. Acetylene and oxygen can be used to good advantage for the welding of thin sheet aluminum, although the welder must manipulate the torch more skilfully to prevent overheating the metal.

Figure 13 shows three illustrations of welds in sheet aluminum made with hydrogen. The lower right hand photograph shows two sheets of aluminum one-eighth inch in thickness, cut straight and true, and placed together ready to be welded. The sheets shown in Figures 13 and 14, thicker than one-sixteenth inches, are prepared in this manner. The lighter gauge sheets one-sixteenth inches and thinner, were flanged at the edges, as illustrated in Figure 8. The three-sixteenths inch sheets, shown in the upper left hand photograph of Figure 14 were bevelled to an included angle of ninety degrees, as shown in Figure 12. This weld is also shown, after it was bent to test its ductility, in Figure 15. All of the sheets shown in Figure 13 were welded with oxygen and hydrogen. Those shown in Figure 14 were welded with oxygen and acetylene. Hydrogen does not produce sufficient heat to weld aluminum sheets thicker than one-sixteenth inch.

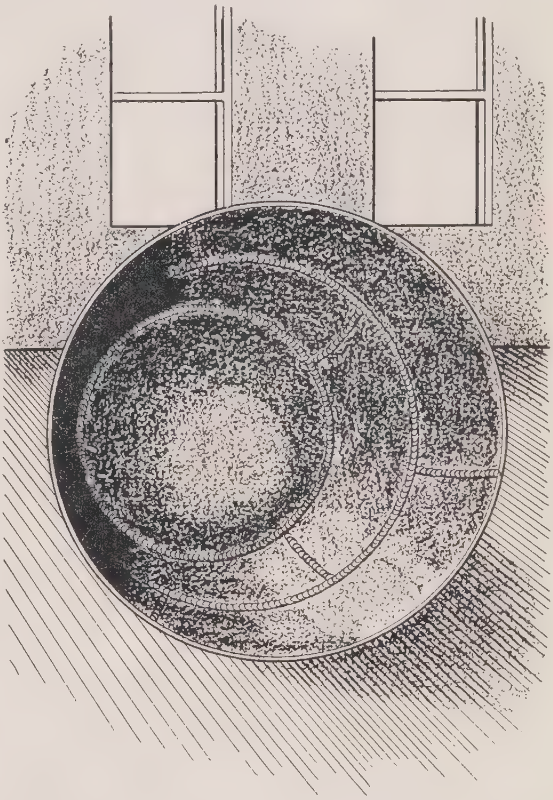


Figure 18—This Sketch Shows the Bottom of the Still with the First and the Second Rows of Plates Formed to Shape and All Welded Together.

Flux Containers

One of the useful accessories for welding aluminum is a container for flux into which the rods can be dipped to coat a considerable length of them. A good flux container should be quite long and of sufficient diameter to contain enough flux, for facilitating the work which is to be done. If, for instance, the welder is working steadily welding aluminum all day, it could be made of brass tubing two and one-half or three inches in diameter and about eighteen inches long. A bottom should be welded into the piece of tubing and brazed or silver soldered to make a water-tight joint, and the container attached to the welding table.

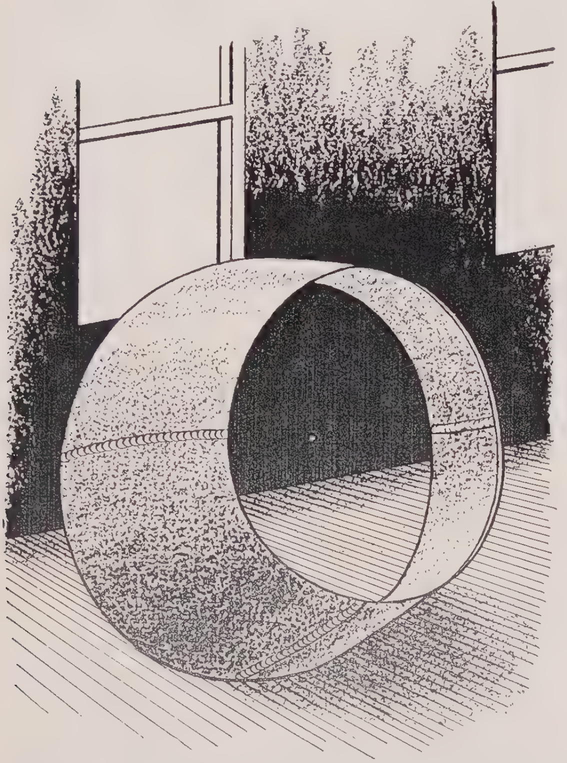


Figure 19—Sketch Illustrating the Upper Ring, Made of Four Pieces of Plate Formed and Welded Together.

The flux should be mixed with water, to the consistency of a thin paste, and the container filled with a day's supply. The welding rods which are in current use can be kept in the container immersed in the flux. Dry aluminum flux will ordinarily absorb a certain amount of moisture and for this reason should always be kept in a closed can or bottle. Some aluminum flux absorbs so much moisture from the atmosphere that it is supplied only in bottles, tightly corked, and sealed with paraffin. Steel does not make a good flux container, because it will corrode; either brass or aluminum should be used for this purpose. Flux which is left over each morning should be thoroughly broken up and again mixed with water.

Welding Aluminum Gasoline and Oil Tanks for Airplanes

Figure 16 illustrates a gasoline and an oil tank for a late model airplane. The gasoline tank to the right is set in the forward part of the fuselage in front of the pilot and to the rear of the engine. The oil tank is located immediately forward of the gasoline tank and there is a fire wall between these tanks and the engine. The gasoline tank, to the right of Figure 16, is made of two pieces of sheet aluminum, one forming the ends and bottom of the tank and the other the semi-circular sides and top. The thickness of this aluminum is No. 20 gauge. These two pieces are formed to shape after they have been beaded around the perimeter of each piece and along the spot-welded joints between the baffle plates placed inside of the tank. These beads are to compensate for expansion and contraction caused by welding. The baffle plates are made of sheet aluminum, with holes punched therein, to permit the free flow of gasoline, and to prevent too much splashing. Two extend lengthwise of the tank and two across the tank as indicated by the rivet-like welds shown in the photograph.

After the baffle plates have been cut to shape, punched and formed, they are placed in position with relation to the tank sheets and welded with spot welds made with the torch as indicated. The two halves of the tank are then placed together and tack-welds are made at intervals of one inch all the way around the seam. This holds the two sheets securely in position and prevents warping during welding. No jigs are used in connection with this seam. The edges of the sheets are butted together and are not flanged in any way.

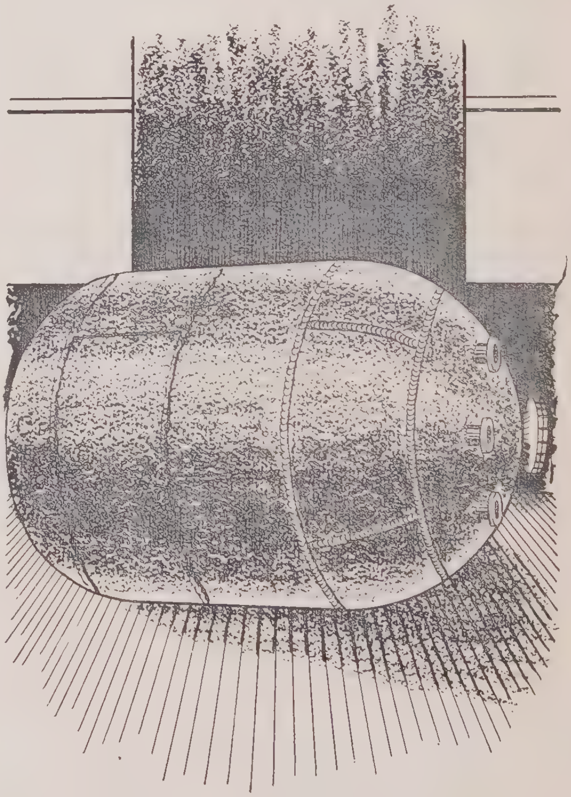


Figure 20—The Completed Still. These Stills Were Tested to 150 Pounds Cold Water Test. They were Designed to Operate Under a Temperature of About 600 Degrees Fahrenheit.

After the tack welding has been finished, the seam is welded completely throughout.

The filling opening of the tank has a circular bead dished inward around the nipple, so that the weld can be made close to the nipple, which is welded in place. The gauge casting immediately back of the filling opening is bolted to a steel flange on the inside of the tank and this flange is riveted to the aluminum sheet. The joint between this casting and the sheet is set up with a compound which makes the joint tight. The outlet of the tank, located underneath, is bolted to an inside riveted flange in the same manner as the gauge casting. The oil tank to the left of Figure 16 is made in generally similar manner, except that it does not contain baffle plates. The oil filling opening is welded to the aluminum sheet and the connection nipples to the oil system of the engine are made of bronze with bolted and riveted flanges on both the inside and outside of the tank. This is a typical sheet aluminum job, requiring very skilful torch manipulation, but presenting no seriously difficult problems to the welder.

Welded Aluminum Vessels for Manufacturing Purposes

In order that the student may understand the extent to which aluminum may be used for various kinds of vessels and containers in food and chemical manufacturing plants, an illustration is taken from a job which was accomplished by the Bournonville Welding Co. in New York City some time ago. A description of this job was published in Chemical & Metallurgical Engineering at that time. The sketches shown in this lesson illustrate the general welding procedure and the completed still. Several stills were made of three-quarter inch cold rolled aluminum plate. They were quite large, having a capacity of 1,900 gallons and they were used for distilling rosin. The test pressure required was 150 pounds of cold water, but the stills were to be operated under a temperature of approximately 600 degrees Fahrenheit and a partial vacuum.

These stills were made of twelve separate pieces. The two ends were dished to shape to form the bottom and top, each of which in turn was welded to the next course made up of four pieces of plate welded together. The center section was made of two pieces rolled to cylindrical shape and welded on opposite sides of the ring thus formed. The pieces were received flat and were formed to shape with a hydraulic press, made particularly for the purpose. The edges were bevelled to an angle of forty-five degrees, making the included bevel at the seam a ninety degree vee. All of this bevelling was done with the air chippers.

The method of preheating was simple. Aluminum, of course, radiates heat very rapidly and it would be difficult to weld successfully aluminum plates as thick as these without some auxiliary heat. For this reason, two two-inch air and city gas torches were used to preheat sections of metal about six inches on each side of the seam just ahead of the operator, as welding progressed. The methods for welding heavy aluminum plates follow closely the principles set forth for heavy steel plates. The object of the preheating torches was to expand the aluminum plates fully, as the weld progressed, ahead of the actual puddle, in order to compensate for the heavy shrinkage taking place as the puddle solidified.

The welding rods used were drawn aluminum rods of about the same grade as the metal of the aluminum plate. Flux was used and in general the same practices heretofore described for the welding of lighter aluminum plates.

There are many jobs of this kind, which could be described and illustrated, but the general principles set forth in this lesson apply to all of them, with the exception of such changes which may be made necessary by local conditions.

Aluminum Solders

The use of aluminum solders cannot be recommended because of the fact that no solder has yet been developed which will not disintegrate and separate from the aluminum after it has been exposed to moisture for a time. Wherever it is possible repairs should be made by welding and not by soldering. There have been a large number of aluminum solders which have been patented and many of these have been tested by the Bureau of Standards to determine their value. In most cases they are combinations of tin, zinc, aluminum, copper, lead, antimony and silver. They are United States, British, French and German patents.

The subject has been of so much interest generally that the Bureau of Standards made a very careful investigation of those patents available and published a circular, No. 78, entitled "Solders for Aluminum." This circular gives the details of these tests and they are summarized by the following general conclusions:

1. All metals or combination of metals used for aluminum soldering are electrolytically electropositive to aluminum. A soldered joint is, therefore, rapidly attacked when exposed to moisture and disintegrated. There is no solder for aluminum of which this is not true.

2. Joints should, therefore, never be made by soldering unless they are to be protected against corrosion by a paint or varnish, or unless they are quite heavy, such as repairs to castings, where corrosion and disintegration of the joint near the exposed surface would be of little consequence.

3. Solders are best applied without a flux or by using paraffin as a flux, after preliminary cleaning and "tinning" of the surfaces to be soldered. The composition of the solder may be varied within wide limits. It should consist of a tin base with the addition of zinc or of both zinc

and aluminum, the chief function of which is to produce a semi-fluid mixture within the range of soldering temperatures.

Suggested Ranges of Composition

Tin-zinc solders:	
Zinc, per cent	15–50
Tin	Remainder
Tin-zinc-aluminum solders:	
Zinc, per cent	8–15
Aluminum, per cent	5–12
Tin	Remainder

4. The higher the temperature at which the "tinning" is done, the better the adhesion of the "tinned" layer. By using the higher values of the recommended zinc and aluminum percentages given above, the solder will be too stiff at a lower temperature to solder readily and the workman will be obliged to use a higher temperature, thus securing a better joint. A perfect union between solder and aluminum is very difficult to obtain.

5. The joint between previously tinned surfaces may be made by ordinary methods and with ordinary soft solder. Only the "tinning" mixture need be special for aluminum.

6. There is no reason why a good solder for aluminum need be brittle as several commercial varieties are, and it is very undesirable that it should be.

7. The tensile strength of a good aluminum solder is about 7,000 lbs. per sq. in. Those with higher tensile strength have, in general, their temperature of complete liquation too high for soldering purposes. The strength of a joint depends upon the type of joint and upon the workmanship. Much dependence should not be placed on the strength of a joint.

Job Sheet No. 16

Welding Cast Aluminum

The student should procure for the work in this job sheet several good sized pieces of cast aluminum from three-eighths of an inch to one-half inch in thickness, and some sheet aluminum about one-sixteenth inch thick. The regular welding torch, with a tip the size of a No. 5, should be used for the cast aluminum; a smaller torch, similar to a No. 2 torch with a tip the size of a No. 23, should be used for the sheet aluminum. A can of aluminum flux should be available for use with the cast aluminum and some sheet aluminum flux for use with the sheet aluminum.

The first work to be done is the welding together of two pieces of cast aluminum. Select two of the pieces, the edges of which will match together, and using a wire brush and gasoline, or hot water, thoroughly clean the pieces on the edge and on both sides of the break. Next mix some of the cast aluminum flux with water until it has a consistency of cream and spread it evenly over the break with a brush. The flux should coat the aluminum for about one-half inch on each side of the crack. A piece of three-sixteenths inch diameter aluminum-silicon alloy welding rod should be coated on the end with the aluminum flux. This may be done by dipping the rod for a distance of several inches into the flux container, in which the flux and water mixture has been placed.

The two pieces should now be tack welded together at each end. It will be found when making these tack welds that in order to fuse together the edges of the two pieces, it will be necessary to use the flux coated end of the welding rod to break up the coating of oxide before the metal will unite.

When the pieces are tack welded together, welding should proceed as outlined in the text of this lesson. The pieces should be heated with the torch along the break for about two inches at one end until the aluminum becomes soft. The puddling rod should then be used to rake out the metal on both sides of the break, until a vee of approximately ninety degrees is formed. This vee should extend downward to within approximately one-sixteenth of an inch from the bottom. After the pieces have been veed out for a short distance, the torch should be moved closer to the metal as shown in Figure 7 of this lesson, and the break filled with metal from the welding rod.

While adding material from the welding rod, keep the end of the rod submerged in the puddle of melted aluminum and in motion. This will cause any oxide or impurities, that may be in the metal, to float to the top of the puddle and will leave the weld metal clean and free of impurities. Be sure to dip the end of the welding rod in the flux mixture before introducing it into the weld. When the first two inches of weld have been made, rake out another short section to a vee, weld that section and so continue on across the break.

The student should continue making these welds in cast aluminum until he is able to judge the fusion point of aluminum accurately, to control the molten puddle, and to make a weld neat in appearance.

Welding Sheet Aluminum

Figure 8 clearly shows the manner in which sheet aluminum, one-sixteenth inch thick, should be flanged preparatory to welding. When making this flange, endeavor to make it just as short as possible, preferably about one-sixteenth of an inch. Too much metal flanged up will not permit the welder to make a neat weld. After the pieces have been flanged, they should be coated with a solution made of sheet aluminum flux and water. They should be placed together and held with clamps similar to those shown in Figure 9.

No filler rod is necessary for welding sheet aluminum, when the edges are turned up in the manner shown; tacking together of the sheets merely consists of melting down a portion of this flange at either end of the piece. When making this tack weld, however, do not start at the end of the piece, as in tack welding steel, but start at a point about three-quarters of an inch from the end of the piece and work towards the end. The tack weld is made by directing the envelope of the flame against the flange until the flange melts down and takes the form shown in Figure 8. After the pieces have been tack welded together, the clamps may be removed and the balance of the flange melted down, thus welding the pieces together.

When melting this flange down, the torch should be held at a flat angle, similar to the small sketch shown in Figure 8. If the torch is directed at too sharp an angle, the heat will be too great and holes will be melted in the thin aluminum. Even with the torch directed at an acute angle, it will be necessary to withdraw the flame occasionally to permit the metal to cool down. After the weld has been started, the torch should be moved along the seam slowly enough to melt the flange and yet too rapidly to melt through the sheets on each side of the weld.

When the weld is finished, turn the piece over to see whether or not sufficient heat was used to form a bead on the underside of the weld, as well as on the top. By forming a bead on the under side, the same strength is developed as if all of the reinforcement had been made on the top of the weld and a neater appearance is obtained. This bead can be hammered flat to the thickness of the sheet if desired. As has been stated in the lesson, much practice is necessary to make a good sheet aluminum welder. However, every welder should practice as much as he can on this work, so that in case he is called upon to weld sheet aluminum, he will know how to do it.

Questions:

1. In what form is aluminum mined?
2. What are some of the valuable properties of aluminum?
3. What effect has oxygen upon aluminum?
4. How are aluminum castings made?
5. Which piece of aluminum will show the greater tensile strength per square inch: A bar one-half inch in diameter, or a bar two inches in diameter? Why?
6. Why should aluminum castings be preheated before welding?
7. What is the advantage of using an aluminum-silicon alloy welding rod when welding aluminum castings?
8. What are the two methods used for welding cast aluminum?
9. How should two pieces of sheet aluminum one-thirty-second inch thick be prepared for welding?
10. What kind of solder should be used for aluminum? Why?

Lesson No. 17

Welding Monel Metal, Nickel, Copper and Various Alloys

MONEL metal is mined, as a virgin metal, near Sudbury, Ontario. It is a nickel, copper alloy of high nickel content, which is mined, smelted, refined and rolled solely by the International Nickel Company. The name "Monel Metal" is a registered trade-mark. Monel metal contains approximately sixty-seven per cent of nickel, twenty-eight per cent of copper and five per cent of other elements, consisting partly of iron, manganese, silicon and carbon, which are introduced in the process of refining.

Monel metal is a silvery-white colored metal, which resists corrosive influences to such an extent that it may be considered practically corrosion-proof. It is used for many purposes, both because of its bright, silvery appearance when polished, and because of its corrosion-resisting qualities. It is used for propellor shafting in salt water; for pump parts; for handling mine water containing acid; for parts of textile machines which come in contact with bleaching and dyeing chemicals. Soda fountain and restaurant equipment are made extensively of sheet Monel metal. Salt driers are lined with Monel metal. Packing machinery parts and equipment, milk handling equipment, turbine blades, pump springs, valves, seats, rods and discs for pumps and a multitude of other parts, made both of rolled and cast Monel metal, are used extensively.

The use of any metal is dependent to a large extent upon suitable methods for joining pieces of it together. The requirements of many machines are such that joints must be gas and liquid tight and a welded joint is always superior in this respect to a joint made mechanically. The weldability of a metal, therefore, determines, to a large extent, its use in the production of machines and equipment. One of the advantages which Monel metal possesses is that it can be easily welded with the oxy-acetylene torch and the joint thus made is tight, strong and ductile.

The melting point of Monel metal, given upon page 114, Lesson No. 7, is 2,400 degrees Fahrenheit, 200 degrees less than that of medium carbon steel. The melting point of nickel is 2,640 degrees. The weight of Monel metal is given on page 119, Lesson No. 7, as 0.318 pounds per cubic inch. It is about thirteen per cent heavier than steel and about twenty-two per cent heavier than cast iron. The tensile strength of Monel metal varies between 65,000 and 100,000 pounds per square inch. It has a heat conductivity approximately one-fifteenth that of copper.

Preparation of Monel Metal Sheets and Plates

It is very essential that all black oxide from the surfaces and edges of Monel metal be cleaned away before welding is begun. This can be accomplished by machining the edges or grinding them until the metal is clean and bright. The edges of plates one-eighth inch and greater in thickness should be bevelled to an included angle of ninety degrees between the two sheets, and cracks or breaks in cast Monel metal should be treated in similar manner.

The bevelling or chamfering of the edges of Monel metal sheets and plates does not differ much from that recommended for steel. In the third sketch, upon page 15, Lesson No. 2, a single vee bevel is shown for plates one-eighth inch in thickness and over. Practice with Monel metal should follow these general lines for butt welds. Flange welds, however, are made in a different manner, as hereafter described. Flange welds are made by bending up the edges of the sheets about one-eighth of an inch in width to an angle of about seventy-five degrees.

Flange welds are recommended for sheets from No. 26 gauge in thickness to No. 16 gauge. These welds are made without tack welding and the sheets are held in suitable jigs. From No. 18 gauge to one-eighth inch in thickness, the flanges may be used and, if desired, they may be tack welded at intervals of about two inches along the entire length of the seam. In this instance the use of jigs is unnecessary as the tack welds will hold the sheets in position. At the same time there is sufficient flexibility in the flanges to prevent distortion or straining of the metal. Butt welds may be made between sheets No. 16 gauge in thickness up to one-half inch plate.

Welding Flux

Monel metal oxidizes very rapidly and it is, therefore, essential to use a flame in which there is no excess of oxygen. It is not believed, however, to be good practice to use a flame with an excess of acetylene, as is recommended by some welders. Too much acetylene produces a flame in which combustion is not as complete as it is with a neutral flame, and with a good torch it is entirely possible to control the neutrality of the flame so that it will not be oxidizing.

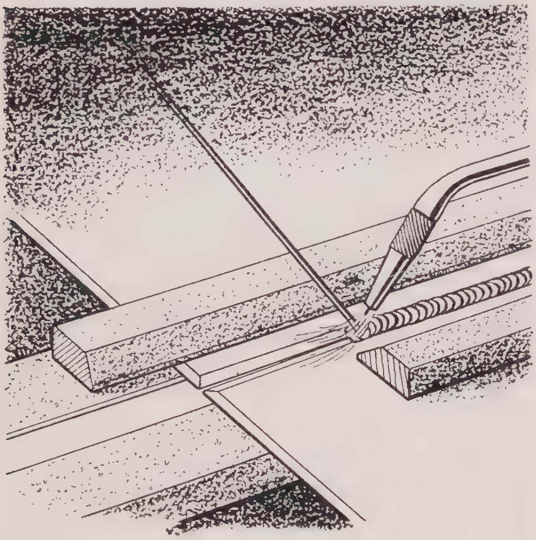


Figure 1—Sketch Showing a Jig Used to Hold Two Plates of Monel Metal in Position During Welding. The Main Plate of the Jig, Made of Cast Iron, is Recessed One-sixteenth of an Inch in Depth Directly Under the Seam. The Torch and the Welding Rod Are Shown in the Correct Welding Position and the Single Vee Bevel Between the Two Plates is Clearly Indicated.

Oxy-acetylene welding can be accomplished without a flux and some excellent welders produce good welds in this manner. It is believed, however, much better practice to use a flux and the beginner will find that welding with a flux is much easier than without. A flux recommended by the International Nickel Company in their No. 1 Bulletin of Working Instructions consists of four parts of boric acid powder and one part of ground borax. The borax and the boric acid powder should be mixed with water until a thin paste is formed. This paste should be applied to the metal with a brush and may be kept ready mixed in a container deep enough to dip the Monel metal rods for a length of several inches.

The practice in this respect in so far as the use of flux is concerned is very much like the practice recommended for aluminum. In some instances 20-Mule Team Borax mixed with water has been found very satisfactory. In all other respects, the welding of Monel metal is very much like the welding of steel. The metal flows like steel and, in fact, can be welded to steel. The tip should be about the same size as that ordinarily used for welding steel of like thickness; and the flame should be adjusted until it is neutral in character. It is not believed good practice to use too large a tip and to adjust the flame until carbonizing.

Welding Rods

Monel metal welding rods should be used, which can be procured in the usual sizes from the sales agents of the International Nickel Company. It is, of course, possible to use strips cut from Monel metal sheets, but in most instances it will be found more satisfactory to buy Monel metal welding rods for this purpose. It is important that the welding rod be held with the end in the puddle and the torch held in such manner that the envelope of the flame covers the puddle and the rod at all times. This is necessary because the metal oxidizes readily and forms a black scale over the surface. It is important to complete the section of weld being made as rapidly as possible and not to weld in layers. For instance, a section of weld two inches in length may be fused at the bottom of the vee, but this two inch section should be completed before the puddle is continued to the next section. In this manner scale and oxidation will be avoided and the result will be more satisfactory.

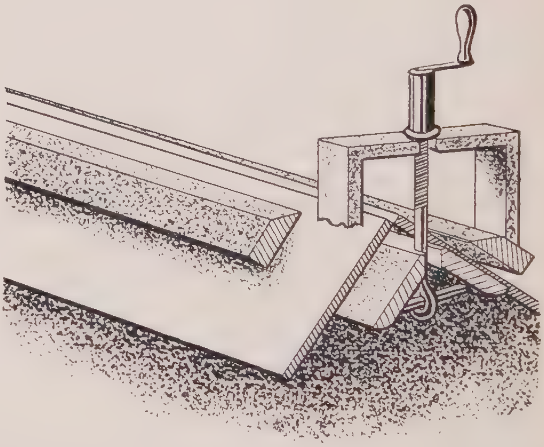


Figure 2—In this Sketch a Suitable Jig is Shown for the Making of a Corner Weld Between Two Sheets of Monel Metal.

Oxide Should Be Floated to the Reinforcing Section of the Weld

The oxide or slag formed by the metal will float to the surface of the puddle. The section of the weld should be reinforced until the thickness of the weld metal is great enough to insure a thickness at least that of the plate, of good, sound metal and that the oxide or slag has been floated to the reinforced section.

A weld made in this manner will, of course, not be as strong as the original plate, because the reinforced section will not have the strength of the solid weld metal. A good weld in Monel metal will, however, have a strength of from forty thousand to fifty thousand pounds per square inch and enough ductility to bend one-quarter inch plate ninety degrees.

The movements of the torch and rod in the puddle, in making a Monel metal weld, are so similar to those heretofore described that it is needless to discuss them at length in this lesson. In Figure 1, the position of the torch and the rod is shown when the weld is being made in heavy Monel metal plate where it is necessary to bevel the edges. The weld may be made by the semi-circular movement method from right to left, as illustrated in Figure 1, or as some welders prefer, by the advanced flame method from left to right. It is believed that in general the welder must determine for himself the movements of the rod which he finds most satisfactory for the conditions under which it is working.

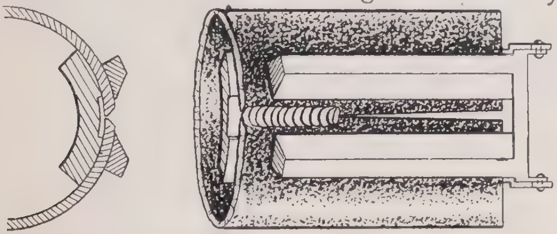


Figure 3—In Welding Cylindrical Tanks, It is Necessary to Hold Securely the Longitudinal Seam in Position During the Process. When the Seams are Very Long, It is Usually Necessary to Spread the Far End of the Seam Two and One-Half Per Cent of Its Length in the Same Manner Recommended for the Welding of Steel Tanks

The principal reason for printing the sketch, Figure 1, has been to illustrate the use of a proper jig for the butt welding of two pieces of Monel metal plate.

Jigs and Clamps

Suitable jigs and clamps are more necessary in welding Monel metal than in welding steel. The practice of tack-welding a seam at intervals, which is quite common in steel welding, does not work in as satisfactory a manner with Monel metal, particularly upon flat work. Tack welding may be resorted to in the assembly of a tank, or other structure, at points where the distortion of the metal caused by heating and cooling it can be controlled; but as a rule, it is much easier to hold the plates or sheets in suitable clamps and jigs and in this manner prevent distortion which would otherwise occur.

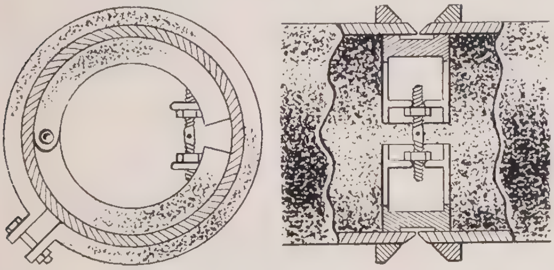


Figure 4—A Good Transverse Seam Jig is Shown in this Sketch. In Making a Long Cylindrical Tank the Transverse Seams Must Line Up and a Jig, Which will Securely Hold the Edges of the Cylinders in Line While Welding Progresses, is Essential. The Inside Ring is so Arranged that it Can be Collapsed to Remove it from Inside the Cylinder.

It has been found in designing jigs and clamps for both Monel metal and Allegheny metal that a very useful device to assist in preventing distortion of the sheets is the insertion of copper lining plates in the arms of the jig and in the base plate. Copper, of course, has much greater conductivity than either cast iron or steel, and will conduct the heat away from the sheets of Monel metal, or Allegheny metal, far more rapidly than the steel arms of the jig or the cast iron base plate. It is not a difficult matter to line the arms and the base of the jig in this manner with copper plates of suitable width and approximately one-quarter inch in thickness. In welding long seams spreading the far end of the seam a distance equal to two and one-half per cent of the length of the seam is as good practice in the welding of Monel metal, as in the welding of steel. When a seam is set in a jig in this manner, the jaws of the jig should not be clamped too tight to prevent the gradual approach of the far edges of the metal as the puddle progresses along the seam.

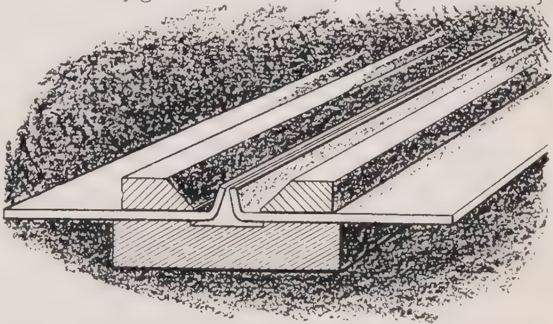


Figure 5—A Jig is Shown in this Sketch for Use with a Flanged Weld. The Edges of the Sheet are Flanged, as Shown, to Angles of Approximately Seventy-five Degrees and Held Securely in Position.

In Figure 1 a jig of this type is shown, consisting of a base plate made of cast iron, in which a depression or recess has been machined immediately under the seam. This recess should be about one-sixteenth of an inch in depth to prevent actual contact of the base plate of the jig with the Monel metal directly under the seam. Such contact would radiate or conduct the heat away from the seam too rapidly. There are no special requirements in the construction of a jig of this kind for Monel metal, except the copper liners before mentioned, and it may be constructed just as such a jig would be constructed for the welding of steel plate.

The bed plate and the bars, however, should be of fairly heavy steel, if copper liners are not used, so that the heat along the seam will not be conducted to too great an extent to the sheets or plates outside of the jig. The object of the jig, it will be understood, is to prevent buckling as much as possible and the success of the jig in this respect will depend to a considerable extent upon its heat conducting properties.

In Figure 2 a similar jig of a much simpler type is shown for the welding of a corner seam. Such a jig would be particularly convenient if a rectangular tank of Monel metal were being constructed. In Figures 3 and 4 jigs are shown, which will be found very useful in the construction of a cylindrical tank. One of these is arranged especially for the longitudinal seam and the other for a transverse seam between cylindrical sections of the tank.

The success of the work is, to a very large extent, dependent upon the care and skill used in setting up the seams correctly and in providing well-made, accurate jigs. Before the job is started, careful consideration should be given to the manner in which the sheets are to be held and if permanent jigs are required, these should be carefully made up. The jigs shown in Figures 1 to 4 inclusive, all apply to butt welds between the sheets or plates.

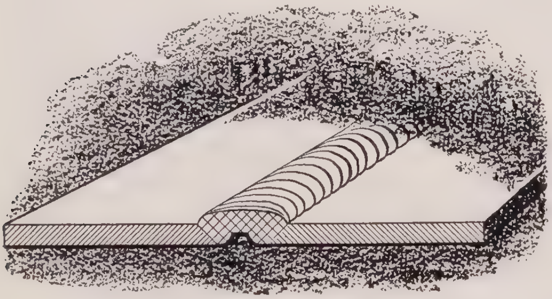


Figure 6—This Sketch Shows the Completed Flanged Weld. It is not Melted Clear to the Bottom of the Flanged Joint on the Inside and Usually the Recess left in this Manner is Filled with Soft Solder.

Double Vee Seams

In welding a joint between heavy plates of Monel metal, where the edges of the plates are double bevelled, as shown in the fifth sketch from the top, on page 15, Lesson No. 2. The first side should be welded as has been described, but the second side should not be welded until the entire seam has been heated to a red heat with preheating torches; otherwise, severe internal strains are likely to be set-up and cause the weld to break.

Flange Welds

Figure 5 shows the edges of Monel metal sheets flanged to angles of seventy-five degrees, as heretofore described. These are held in position in a jig, arranged for the purpose, and the flanges are placed so that they come as close together as possible. Before being placed in the jig, the flanges are coated on all sides with flux. This is applied with a brush in paste form, and the sheets clamped tight in position. A Monel metal welding rod of correct thickness is dipped into the flux container and the edges and the rod fused together until the finished seam is similar to the section shown in Figure 6.

The flange weld makes a very stiff seam in a tank, or container, and where cleanliness on the inside of the seam is required, or corrosion is feared, the inside of the seam may be finished smooth and even with the inside of the tank by applying soft solder. This will adhere nicely to the surface of the Monel metal, and make a clean, smooth job. Soft solder applied to the back of a seam in this manner is shown in Figure 12.

Welding Monel Metal Castings

When Monel metal castings are to be welded, the crack should be veed out to an angle of approximately ninety degrees by grinding with a portable grinder. Castings should be preheated in a rough fire-brick preheating furnace, as described in Lesson No. 16, for aluminum castings. They should be heated until a cherry red about 1,250 degrees Fahrenheit. When heated in this manner, they are quite likely to warp, as is the case with aluminum castings and, therefore, they should be very carefully supported, as described in Lesson No. 16. They should also be carefully handled, if necessary to shift their position while hot.

Rapid cooling is quite likely to set up severe internal strains in Monel metal castings and cooling should be accomplished very slowly, as has been described for cast iron. Pure Monel metal welding rods should be used and the weld may be made with or without flux, as desired by the welder. If the weld is made without flux, care must be taken not to mix the oxide or scum, which forms on top of the molten puddle, with the melted metal. The welding rod is thrust through the coating of oxide on top of the puddle and is held in the molten puddle with the envelope of the flame covering all of the melted metal. All puddling is done underneath the surface of the puddle and the rod is not removed any more than is necessary. All of the oxide possible is floated to the surface and if it becomes too heavy, or interferes with the operation of the rod, it may be scraped away from the surface with the rod and a new start made.

When flux is used, the method is generally similar to the flux method for welding aluminum castings, except that the degree of heat is, of course, far greater. With these remarks the welder should have no difficulty in welding Monel metal and should require only a few hours of practice to accomplish good results.

Welding Monel Metal Torch Handles

The use of Monel metal has extended to the manufacture of welding and cutting torch handles. Monel metal tubing of the correct diameter and thickness was difficult to secure and for this reason the manufacturer of these torches procured flat Monel metal sheets and pressed these sheets with dies to form the corrugations and the name-scroll required. These pressed, flat sheets were then rolled to form the cylindrical handles. Figure 7 shows a photograph of one of these handles unwelded after the flux had been applied. It will be noted that the metal after being thoroughly cleaned was covered with a flux made of borax mixed with water to a paste. The flux was applied with a brush to each handle which was then placed in the jig, as shown in Figure 8. In this photograph the welder is welding a seam between the flanged edges of the Monel metal, just as easily, and with the metal flowing just as freely, as would be the case if the handles were made of steel.

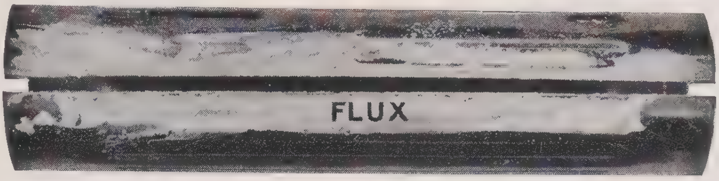


Figure 7—Photograph Showing a Handle for an Oxy-Acetylene Torch Prepared for Welding by Flanging Up one Edge. The Handle is Shown in this Figure, Coated with Flux, Ready for Welding.

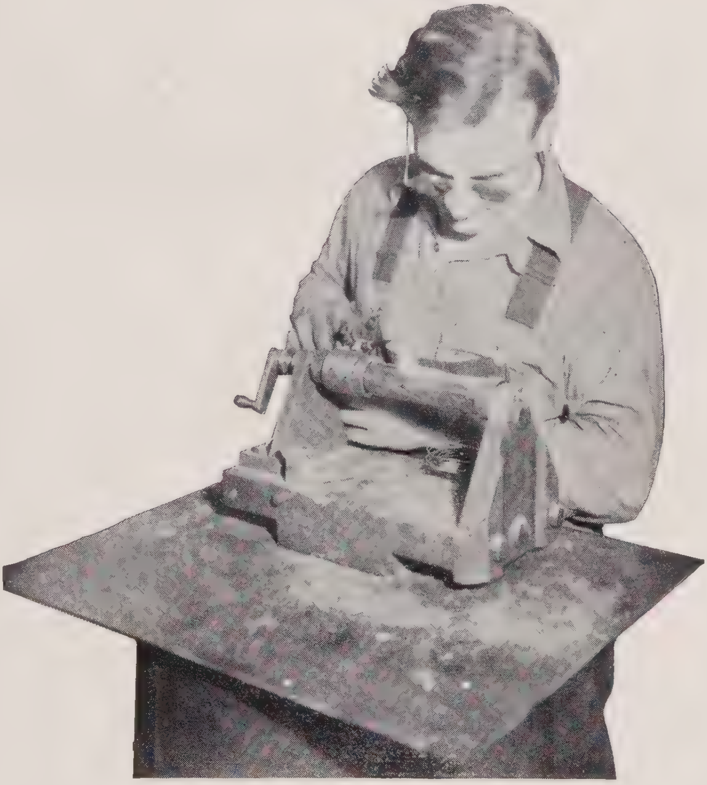


Figure 8—Photograph Showing the Jig Used for Welding These Handles and the Process of Welding. The Metal Flows in a Bead very much Like Steel.

One edge of the Monel metal handle was flanged at right angles a little more than the thickness of the metal. In welding this edge was fused with the other edge without the addition of filler rod, except to start the weld, or if a very little Monel metal was needed to round out the bead. Figure 9 is a photograph of the finished weld upon one of these handles.

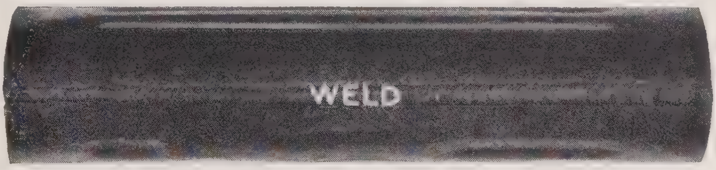


Figure 9—Photograph Showing the Completed Weld in a Torch Handle. These Handles are all Made of Monel Metal.

Welding Nickel

Practice for the welding of nickel does not materially differ from that already discussed for Monel metal. It is, therefore, unnecessary to go into further detail in this connection. Nickel sheets and castings can be welded, with pure nickel welding rod in the same manner as Monel metal.

Welding Everdur

Everdur is an alloy of copper, manganese and silicon made by the American Brass Co. It is rich in copper and possesses some qualities which render it an extremely useful alloy. It resists corrosion, possesses good machining qualities and is a strong, ductile metal. Hot rolled Everdur tank plates are supplied in thicknesses from three-sixteenths inches up to one inch for use in large, hot water storage tanks, pressure vessels, etc.

The tensile strength of these plates is from sixty to sixty-five thousand pounds per square inch and the elongation in eight inches is from thirty to forty per cent. This exceeds the tensile strength of boiler plate specified by the boiler code of the American Society of Mechanical Engineers, both in tensile strength and elongation. It is twice as strong as cold rolled copper plate and just as ductile.

It can be welded with the oxy-acetylene torch without difficulty. The strength of the weld metal in a good weld is approximately fifty thousand pounds per square inch. Everdur metal can be made into castings and these castings are readily welded with the oxy-acetylene torch, using Everdur welding rod. Cleaning of the sheets or plates is necessary before welding, and if the plates are hot rolled, they may be either sand-blasted or dipped in a five to ten per cent solution of sulphuric acid heated to a temperature of approximately 140 degrees.

The addition of small quantities of silicon to copper eliminates oxygen, and drives off hydrogen contained in the metal formed during melting. Silicon and manganese added to copper in correct proportions give copper a strength close to that of steel and the alloy has the non-corrosive advantages of copper.

The black oxide, which covers hot rolled sheets and plates, can be removed by sand-blasting, by grinding, or machining. Heavier plates should be bevelled to included angles of ninety degrees, as usual for other metals. Suitable jigs are advantageous and with Everdur a backing bar, or plate, directly under the seam will be found of much assistance. In welding Everdur, the puddle is larger than is ordinarily the case with steel, and the backing bar prevents the molten puddle from falling away from the seam. Copper makes the most successful backing bar, but either cast iron or heavy steel can be used if necessary. A copper liner placed over the cast iron base of the jigs described for Monel metal can be used to good advantage. In welding Everdur the best results are obtained when using a flux. Borax, which has been fused and ground, gives good results, but Anaconda Publication No. E2, published by the American Brass Co., recommends the use of a flux composed of ninety per cent of fused borax and ten per cent of sodium fluoride. The seam is dampened with water and the flux is sprinkled over the surface in a very thin coating.

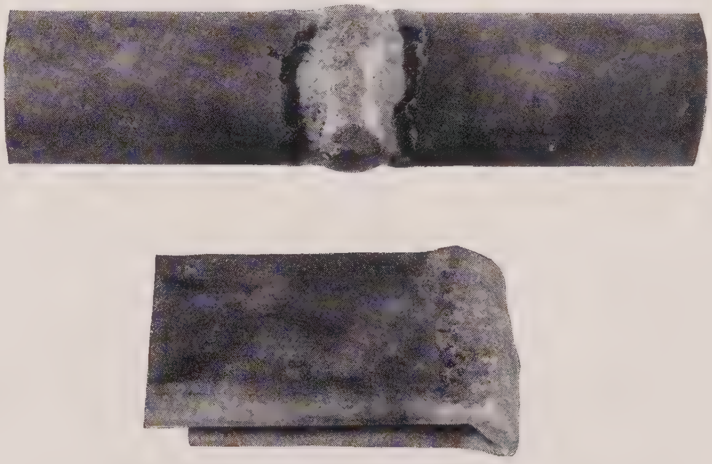


Figure 10—Photograph of a Weld Made Between Two Pieces of Everdur. This Tubing was Welded with Everdur Welding Rod and the Flux Described in the Text. The Photograph was Made Just as the Tubing Appeared After the Welding was Completed. The Flux is Shown Coating the Surfaces Adjacent the Weld. The Flux Should be Cleaned Off of the Tubing, Before a Joint of this Kind is Placed in Service.

The flame should be neutral in character, care being taken to see that it is not carbonizing in any respect. An excess of acetylene in the flame is likely to result in the absorption by the molten metal of carbon monoxide with the result that the weld will be porous. If anything, the flame should favor the oxidizing side of neutrality. Everdur castings are welded as other castings of copper alloys and practice does not materially differ.

Brazing Everdur

Everdur metal can be brazed or soldered in much the same manner as copper and bronze. The fluxes used for welding will produce satisfactory results for brazing. For soldering Everdur a mixture of zinc chloride and hydrochloric acid will make a good flux. The melting point of Everdur given on page 164, Lesson No. 11, is 1,866 degrees Fahrenheit.

Welding Copper

Some years ago welders found it very difficult to weld copper. In fact, many of the older and more experienced men have considered copper one of the most difficult metals to weld. The reason for this lies in the affinity of molten copper for oxygen. The puddle of the weld will rapidly absorb a large quantity of oxygen from the air, which, combining with the copper, forms cuprous oxide which dissolves in the hot metal. The oxide thus formed in the weld metal and in the boundary along the side of the weld, where the weld metal joins the copper plate, makes the metal brittle, weak, and porous.

For many years welds made in commercial copper, or even with electrolytic copper, with pure copper rods were not satisfactory, because they cracked upon cooling and the metal was very porous. Welders resorted to all sorts of flame manipulations, adjustments of the flame, and various fluxes to overcome this difficulty, but these did little good, because the characteristic of copper, which caused this trouble, was not understood and corrected.

There are three principal grades of copper available, called Lake, Electrolytic and Casting. The Lake copper is concentrated from ores found in northern Michigan. Electrolytic copper is made largely from the Western ores, which contain, besides copper, quantities of silver and gold. By the electrolytic process the silver and gold are separated from the copper and the reclamation of these metals warrants the additional expense of electrolytic refining. Casting copper is made from ores, which do not contain enough gold and silver to warrant the use of the electrolytic process. Electrolytic copper as it comes from the electrolytic bath is very pure, having only about one one-hundredth of one per cent impurity.

Copper, however, is usually recast after refining and in the process gases, including oxygen, are absorbed while the metal is molten; these reduce the purity considerably. Much of the cuprous oxide thus formed is removed by the addition to the molten metal of deoxidizers which absorb the oxygen. One of these methods is the covering of the molten copper with charcoal and stirring this molten mass with green hardwood poles. The charcoal and the green wood absorb the oxygen from the copper, thus reducing the impurities to within commercial limits.

The average copper supplied in the form of rods, plates, castings, etc., is about 99.88 per cent pure copper and in some grades of recast copper this purity is much lower. While this degree of purity is sufficient for rolling and drawing copper, for commercial purposes, there is too much oxygen in it to permit a strong weld. For this reason, the welding of ordinary commercial copper should not usually be attempted by the welder.

In recent years, copper has been supplied by manufacturers in the form of plates, bars, rods, castings, etc., known as deoxidized copper. Deoxidation is the result of the addition of silicon which absorbs the oxygen from the copper. It is also possible to purchase deoxidized copper welding rods. The sizes and weights of these rods which are patented, the number being 1,581,417, are given upon page 164, under the name of silicon copper. In these rods, as well as in the plates, bars, etc., a slight additional quantity of silicon is used, thus providing for the absorption of oxygen during welding. When deoxidized copper plates, or bars, and welding rods are used, the difficulties in welding copper disappear, and the metal flows together without the former porosity and brittleness and produces strong, sound copper welds. There are other patents covering welding rods, one of these, No. 1,525,058, claiming a copper rod containing substantial amounts of silicon and manganese. Another patent, No. 1,680,844, claims a copper and silicon rod, the silicon content being from 1.25 per cent to 4 per cent. This is more silicon than the 0.35 per cent claimed in patent No. 1,581,417.

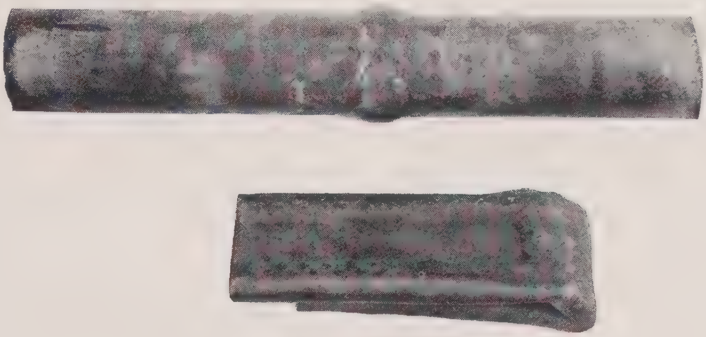


Figure 11—This Photograph Shows Two Pieces of Deoxidized Copper Tubing, Welded with Silicon Copper Welding Rods and No. 3 A-Mal-Gam Flux. The Tubing Has been Squeezed in a Vise until Flat and then Folded Over About the Weld to Show the Strength and Ductility of the Metal.

In many text-books, and in some of the publications directly referring to the welding of copper brasses and bronzes, recommendations will be found for the use of copper welding rods, containing up to one per cent of phosphorus. It has been claimed that successful welds can be made in commercial copper with welding rods containing phosphorus, to absorb the oxygen contained in the copper. It is true that many welds have been made in this manner, but usually there is a zone or area close to the weld, where the weld metal joins the metal of the plates being welded, which has not been influenced by the phosphorus content of the rod; the result is the metal, adjacent the extreme edges of the molten puddle, has absorbed oxygen and has become brittle and porous. It is likely, therefore, that in spite of the pains taken by the welder, the weld may break, not through the weld itself, but along side the weld. If it does not break or crack upon cooling, it is likely to give way when later subjected to any great stress.

It is, therefore, much better practice to avoid, as far as possible, the welding of any but deoxidized copper plates and sheets. As these can be obtained in the market, all new work requiring welding should specify deoxidized copper and not other grades. It is important, therefore, that the welder should be able to distinguish between copper, which can be welded, and that which is essentially unweldable. An excellent method, to determine whether the copper contains too much cuprous oxide to be readily welded, is to heat a piece of the plate to a bright red and hammer it upon an anvil. If the copper is brittle and breaks under this hammering, it should not be welded. If, however, it does not break, it is weldable copper.

The tensile strength of annealed copper varies from 30,000 to 40,000 pounds per square inch. When the copper is cold rolled, or drawn, the strength is increased from 50,000 to about 70,000 pounds. Copper castings have a tensile strength of from 20,000 to 30,000 pounds. Welds made in commercial copper plate have about half the strength of the plates and will usually break just along side of the weld. Welds made in deoxidized copper plate will closely approach the strength of the plate itself, and a break will occur, as a rule, through the weld and not in the zone along side of it.

In welding deoxidized copper with deoxidized copper rods, some welders will recommend the use of a flux and others will state that no flux is necessary. A standard brazing flux, however, similar to A-Mal-Gam No. 3, will be found very successful and convenient in welding deoxidized copper. The metal will flow more readily and is cleaned and protected by the flux during welding.

In welding copper a neutral flame should be used, and the luminous cone of the flame should not come too close to the welding rod or the molten metal. The melting temperature of copper is about 1,980 degrees, considerably lower than steel; but copper has a very high heat conductivity. As the heat is conducted away very rapidly, it is almost always necessary to protect a jig, or table, used to support the plates to be welded with asbestos paper, or other means for heat insulation. It is often necessary to use a slightly larger tip than would otherwise be required for a similar thickness of steel.

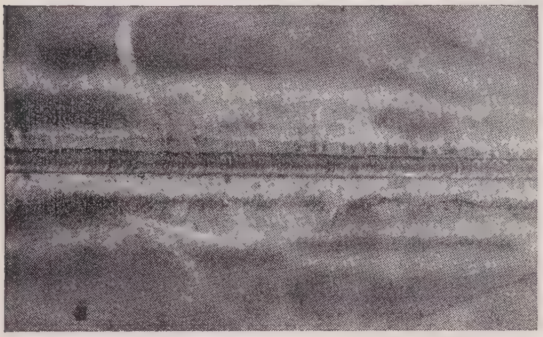


Figure 11—Photograph Showing a Flange Welded Joint, Between Two Pieces of Allegheny Metal. The Two Edges were Bent Over Almost to a Right Angle and Placed Closely in Contact. The Seam was Run Without Flux by Using a Small Tip and Keeping the Flame Constantly Covering the Molten Puddle.

When welding heavy copper plate, or castings, preheating is almost always necessary. In Lesson No. 16, upon page 239, the welding of rosin stills, made of three-quarter inch aluminum plate, is described and a method for preheating the seams of these stills just ahead of the zone of welding is given. Similar methods should be used for welding heavy copper plates. This additional heat is necessary as an auxiliary source of heat, to offset the high conductivity of the metal, and to enable the much smaller flame of the torch, despite its high temperature, to melt and control the puddle. Preheating should usually be sufficient to heat the metal to a dull red.

Copper, when it is melted, is quite liquid and the welder is likely to find the puddle hard to control. This can be overcome by placing a backing plate under the weld to support the puddle, when necessary, and by closely watching the temperature and controlling the degree of heat with the torch.

In other respects, the welding of deoxidized copper can be considered generally similar to the welding of steel; the same principles relating to expansion and contraction apply. It should be remembered that copper has very little strength when hot. Contraction strains as the metal cools are, therefore, very likely to break the hot metal unless care is taken to prevent them.

Deoxidized copper plates, bars and rods can be welded with Everdur welding rod very successfully where the color of the Everdur metal is not objectionable. In making a weld with Everdur, there would, of course, be a slight difference in the color of the weld metal and that of the copper plates or rods, but the weld is strong, solid and at the same time very ductile.

Welding Allegheny Metal

Allegheny metal is a non-corrosive alloy, which is being used for many purposes where its non-corrosive qualities, strength and cleanliness are advantageous. It is manufactured by the Allegheny Steel Co. of Brackenridge, Pa., and is recommended for parts of hotel and restaurant equipment; for dairy and creamery equipment; in meat packing plants; for laundry machinery; chemical plant equipment, etc. It is an alloy containing principally iron, chromium and nickel. A typical analysis is as follows:

Nickel	7.00 to 10.00 per cent
Chromium	17.00 to 20.00 per cent
Carbon	0.20 per cent or less
Manganese	0.50 per cent or less
Silicon	0.50 per cent or less
Sulphur	0.025 per cent or less
Phosphorous	0.025 per cent or less

When annealed, Allegheny metal has an ultimate tensile strength of approximately 90,000 pounds per square inch. Allegheny metal is lighter than Monel metal, or the coppers or brasses, and with special welding rods and a special flux it can be welded without difficulty.

Because Allegheny metal warps, to a considerable extent, when welded a flanged joint is recommended, similar to that shown in Figure 11. These pieces of Allegheny metal were placed together, after the edges had been flanged upwards, as described for the welding of Monel metal, and the seam was welded between the two edges without the use of flux. A very small flame was used and the flame was neutral in character. Strips of Allegheny metal are often used to start a seam of this kind, but after it is once started, no filling rod is required, unless there is a hole or a low spot which must be filled up.

In welding Allegheny metal, as in other iron, nickel, chromium alloys, it is essential to hold the flame constantly over the molten metal to prevent air from reaching the puddle. If the air comes in contact with the puddle, oxidation will take place and the surface will have a porous, blistered appearance and the weld will be weak. A flanged seam of this type makes a stiff, rigid joint. It has, however, the disadvantage that when used for dairy equipment the back of the seam forms a long pocket, where milk, cream or butter might collect and sour. For this reason, in the manufacture of dairy equipment, it is frequent practice to fill in this long pocket with soft solder.

When soldering, a muriatic acid flux may be used, but it must be washed from the surface after the work is completed, because muriatic acid will attack the metal. The principal requirement when soldering is to heat the metal hot enough, so that the solder will flow and "tin" readily. In Figure 12 one-half of the inside of the seam, shown in Figure 11, has been soldered and the other half has been left just as it appeared after welding. The right hand half of the specimen has been polished, while the left hand half was unpolished. A seam soldered in this manner, after being welded, makes a strong, cleanly joint.

Welding Stainless Steel

Carpenter stainless steel, made by the Carpenter Steel Co. of Reading, Pa., is manufactured in several grades, the principal of which are Nos. 1, 2 and 3. These are used for various purposes, where a strong, non-corrosive steel is required. The No. 1 grade contains iron, from twelve to fourteen per cent of chromium, and 0.1 per cent of carbon. No. 2 varies in carbon content and No. 3 is higher in chromium and also contains a small amount of copper. The melting point of the No. 1 grade is given as 2,715 degrees Fahrenheit.

These stainless steels, as well as others, can be welded with the torch. The preparation of the metal should, if possible, be as described for Allegheny metal, making a flanged weld, although a butt weld can be made, if this type of weld is essential. Borax may be used as a flux if desired. An important practise in welding, which must be kept in mind, is the correct manipulation of the torch. The flame, which should be neutral in character, must constantly cover the puddle of metal, as already recommended for Allegheny metal. If the molten puddle comes in contact with the air, it will quickly oxidize and produce a porous, blistered surface and make a weak weld.

Welding rods of stainless steel can be obtained from the Carpenter Steel Co. and should be used unless strips of sheet are available. The rods may be dipped in borax and water, if desired, and the edges of the metal may be coated with this solution.

An excellent device for preventing oxidation in welding stainless steel, if required, is an auxiliary burner using hydrogen, or city gas and air to continuously cover the molten puddle with a flame of non-oxidizing gases, if the welding torch must be removed from time to time. Wherever the torch can be maintained constantly over the molten puddle, as in making an edge weld, similar to that shown in Figure 11, the auxiliary flame, of course, is not necessary.

These stainless steels may be brazed with Tobin Bronze, using A-Mal-Gam as a flux if desired. Of course, the bronze seam will differ in color from the stainless steel, but the joint will be strong and serviceable. The principles required for brazing stainless steel do not differ from those given for other metals and there need be no further discussion of the subject in this lesson.

Inconel

Inconel is a corrosion resistant alloy containing about 80% of nickel, 14% of chromium and 6% of iron made by the International Nickel Company. Annealed sheets of Inconel have an ultimate breaking strength of 80,000 to 95,000 lbs. per sq. in., and the per cent elongation is 40 to 55.

In welding it is necessary to use a flux, especially made for chromium bearing alloys, and an Inconel welding rod. The flux is mixed with water to a thin paste and spread over the surfaces and edges of the sheets with a brush. The rod may be dipped in a long container filled with the mixture of flux and water. A carefully adjusted flame should be used with a very slight excess of acetylene. Proper jigs and clamps are necessary to prevent buckling and warping of the sheets.

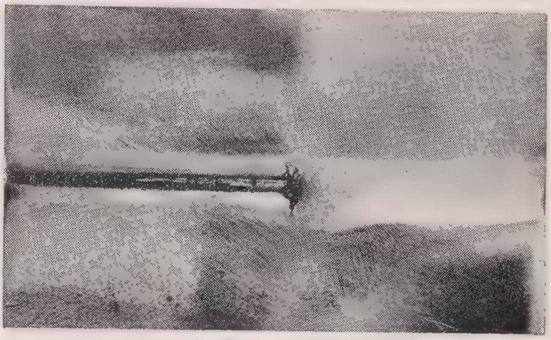


Figure 12—This is a Photograph of the Inside of the Seam Shown in Figure 11. The Right Hand Half of this Seam has been Filled with Soft Solder and Polished. The Left Hand Half of the Seam is Shown Just as It was After Welding. Soldering the Inner Side of a Seam of this Type Makes the Inside of the Metal Clean and Sanitary.

Other Alloys

There are several hundred other alloys, which are used in manufacturing the great variety of machinery and equipment produced for modern industry. Some of these alloys can be welded readily and others will be found extremely difficult to join with the torch. This lesson, however, has given certain principles, applying to the welding of the alloys, mentioned, which can be used in other instances at the discretion of the welder. Whether or not an alloy can be welded will depend upon a number of different conditions. It is important that the approximate melting point be known and the approximate composition of the metal. It is important also to determine whether or not a flux is required, or whether oxidation can be prevented by maintaining the flame in close proximity to the metal to be sure that the molten puddle is always covered by the envelope of the flame. With some alloys it is essential to control the warpage caused by excessive expansion, and in some instances only certain types of seams may be welded, while others may be found very difficult. It is also possible in some cases to make certain types of joints, where expansion and contraction can be controlled, and where jigs or fixtures of some kind, may be conveniently used. All of these matters must be determined by the welder for the particular alloy which he desires to weld and a few experimental pieces, to which he applies the torch, will indicate to him whether or not he is likely to make a success of welding the alloy.

Clad Steels

Clad steels are usually steel plates on which thin veneers of nickel, chromium, or other metal cover the surfaces on one side. The veneer is quite thin, compared to the thickness of the plate, to which it is thoroughly bonded in the process of manufacture. The result is a plate having the strength and other qualities of steel plates, but having one side corrosion resistant. If nickel is the corrosion resistant metal used, the steel is called nickel-clad steel and this is one of the more common types.

Nickel-clad steel plates are less expensive than plates of similar strength made from pure nickel and are therefore used where corrosion attacks only one side of the plate, as in a tank where the contents would be injured by corrosion with the steel plates, or the plates themselves would be eaten away.

In welding nickel-clad steel plates the steel side is veed in the usual manner and welded first, using ordinary steel welding practice. The plate is then turned over and all "icicles" and scale caused by welding on the steel side cleaned away. This is usually done with a round nosed chisel by chipping a groove slightly deeper than the depth of the nickel cladding. A pure nickel rod is then used to weld a bead into the groove, thoroughly bonding the cladding and the steel together, thus completing the joint. In welding the nickel great care must be taken to maintain a correct adjustment of the flame. It should have a slight excess of acetylene and the pressures of the oxygen and the acteylene should be turned down until the flame is "soft," even if the next size larger tip must be used. The nickel rod is ordinarily used bare without flux, but some operators may prefer flux and in this case a special nickel may be used sparingly. The flux, however, must not be relied upon to correct conditions caused by poor adjustment of the flame.

Job Sheet No. 17

Welding of Alloys

The welding of various alloys has been described in the text of this lesson. In the near future the welding of the alloys, described in this lesson and many others, will form a very large field for the welder. In fact, it is believed that every welder, in order to meet the needs of his customers, will find it necessary to know how to weld all of these various alloys.

At the present time, however, it may be difficult for many students to obtain pieces of the alloys described in the text. This job sheet does not, therefore, specify any particular alloy to be welded, but instead it is urged, that the student does his utmost to obtain pieces of at least one of the metals mentioned, and proceed to weld them as described.

Questions:

1. What advantage has Monel metal over steel?
2. What type of rod should be used for welding Monel metal?
3. What is the black scale that forms on top of Monel metal when it is heated, and how is this scale removed?
4. Why are jigs and clamps necessary when welding Monel metal?
5. What is the reason for lining the jig with copper plate?
6. What is the difference between Monel metal and Everdur?
7. What is deoxidized copper?
8. How does it differ from electrolytic or commercial copper?
9. Describe a simple method used to determine whether or not a certain piece of copper is weldable?
10. In general, what type of rod should be used for welding these special alloys?

Lesson No. 18

Lead Burning--Building Up Battery Terminals--Soldering Automobile Radiators

LEAD burning is a common trade name for lead welding. It is not a correct name, because the lead is not burned, but only melted, just as in the fusion welding of other metals. It is much better to speak of the process as lead welding, than lead burning, but it has been given this title in this lesson, because of the fact that lead burning is the customary name for the joining of lead by melting its edges together. Lead has a melting point of approximately 620 degrees Fahrenheit. It is a malleable and ductile metal, but has so little tenacity that it can be drawn into wire only with difficulty. The metal flows under a very slight strain and its elasticity is low. Its heat conductivity, as shown upon page 16, Lesson No. 2, is at the bottom of the list of the metals given. It has a tensile strength of from 1,600 to 2,400 pounds per square inch. In casting, lead shrinks 0.3125 inches per foot. It weighs 0.4106 pounds per cubic inch.

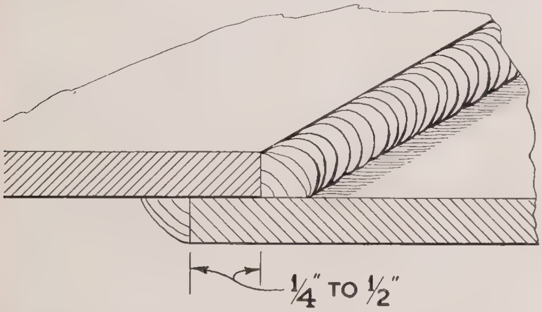


Figure 1—This Sketch Illustrates a Lapped Weld Between Two Lead Sheets. The Oxide Should be Carefully Scraped From the Surfaces and the Edges of Both Sides of Both Sheets, So that the Lap Will be Between Clean, Lustrous Metal Surfaces. A Wooden Mallet May be Used to Pound the Seams Together Lightly to Force the Lapped Surfaces into Close Contact. The Weld is then Made First on One Side of the Sheet and Then on the Other Side. Such Seams May be Made Either Horizontally or Vertically.

Lead Ore Is Mined in Missouri

Practically all of the lead on the market is obtained from sulphide of lead ore, known as galena. Chemical lead, from which sheets and pipe are made, which are used extensively in the chemical industries where acid is encountered, comes largely from southeastern Missouri. It is made from ores, which also contain copper, cobalt, nickel and other impurities. This metal is naturally alloyed with certain ingredients which render it more resistant to the effect of acid than pure lead. Some other lead sheets and pipe contain from six to ten per cent of antimony. This alloy of lead is also extensively used in the chemical industries. Its tensile strength is said to be twice that of chemical lead and it is stiffer and more rigid. It is even more resistant to the action of acid than chemical lead and will not stretch, or buckle, to as great an extent.

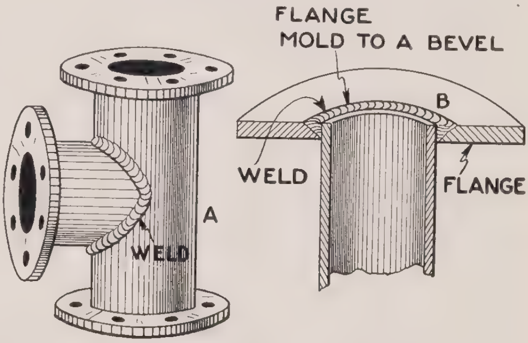


Figure 2—This Sketch Shows a Flanged Tee Made of Lead Pipe and Flanges, Both the Flanges and the Pipe Having Been Welded Together with the Lead Burning Torch. The Tee is Shown at A and at B is a Sectional View Illustrating the Method of Bevelling the Flanges, and Extending the Pipe Through the Opening to the Upper Surface of the Flange, to Make Welding More Simple.

Sheet lead is ordinarily specified by its weight per square foot; for instance, one pound lead, that is lead weighing one pound per square foot, is nearly one sixty-fourth of an inch in thickness. Three and one-half pound lead is nearly one-sixteenth inch in thickness, while seven pound lead is nearly one-eighth inch in thickness and so on. These weights continue in even pounds and five pounds up to sixty pound lead, which is approximately one inch in thickness.

Chemical Industries Use Lead Extensively

In the chemical and paper industries, a great many tanks are lined with lead, drains are covered with lead, and lead piping is extensively used.

The reason for this extensive use of sheet lead and pipe is, of course, its resistance to the corrosive action of the chemicals and acids used in the various processes. When welding sheet lead, it is always important to support the lead sheets, because of the low strength of lead and the tendency of the sheets to sag and buckle. It is very easy to weld lead, but on account of its low melting point, a certain skilful manipulation of the flame is required to prevent overheating the metal; overheating causes it to run away, leaving a hole. Lead fuses readily, particularly the alloy containing antimony. There are no difficult problems with expansion and contraction, because the lead sheets, or pipe, will stretch and bend readily.

Figure 3—Photograph Showing Operators Casting Lead Grids for Storage Batteries. The Operator in the Foreground is Pouring Molten Lead From a Ladle Into a Grid Mold. This Photograph and those Following, Showing the Manufacture of Storage Batteries, Were Taken in the Factory of the Grant Storage Battery Co., at Minneapolis.

Oxide Coating Must be Removed

The surface of lead sheets is covered with a dull, grey oxide, which is caused by the oxidation of the metal from the oxygen in the air. This oxide coating must always be scraped away from the surface before the sheets are welded together. Because the metal is soft, this scraping process is very easy and tools, called scrapers, can be obtained which are made especially for this purpose. Welding rods are usually made of strips, cut from the lead sheet, and these, too, must be carefully scraped to eliminate all of the oxide and show a bright, lustrous surface, before they are used for welding. Lead is always welded by the fusion process; that is, the metal is actually melted and the molten puddle from the two sheets run together. A lead seam, between two sheets, is not expected to have very great strength, and for this reason, strength is not usually a factor in welding a seam, but it is essential that the seam be absolutely tight; tightness cannot be obtained without thorough fusion of the metal.

Hydrogen Often Preferred for Lead Burning

For many years, hydrogen and oxygen were preferred by lead burners, and it was considered that these gases were the only gases which could be used to burn lead properly. Since the extensive use of the oxy-acetylene torch, however, oxygen and acetylene have been used more and more for lead burning until today there are many chemical plants where the lead burners use these gases exclusively. Of course, on account of the very high degree of heat produced by the oxy-acetylene flame, it is necessary to use a very small torch, and in most cases manufacturers supply what are called lead burning torches, producing very small oxy-acetylene flames.

Acetylene Produces a Clean Flame

Such a flame is clean and, if skilfully manipulated, will burn lead more rapidly than hydrogen and enable the operator to make a narrower seam. It is good practice to use a slight excess of acetylene. There are, of course, many lead burners who prefer oxygen and hydrogen and where hydrogen is obtainable, it can be used if desired. The oxy-hydrogen flame is, of course, a very soft, clean flame, there is less oxidation of the surface with it, and while it is not quite as concentrated as the oxy-acetylene flame, it is a good flame for the purpose.

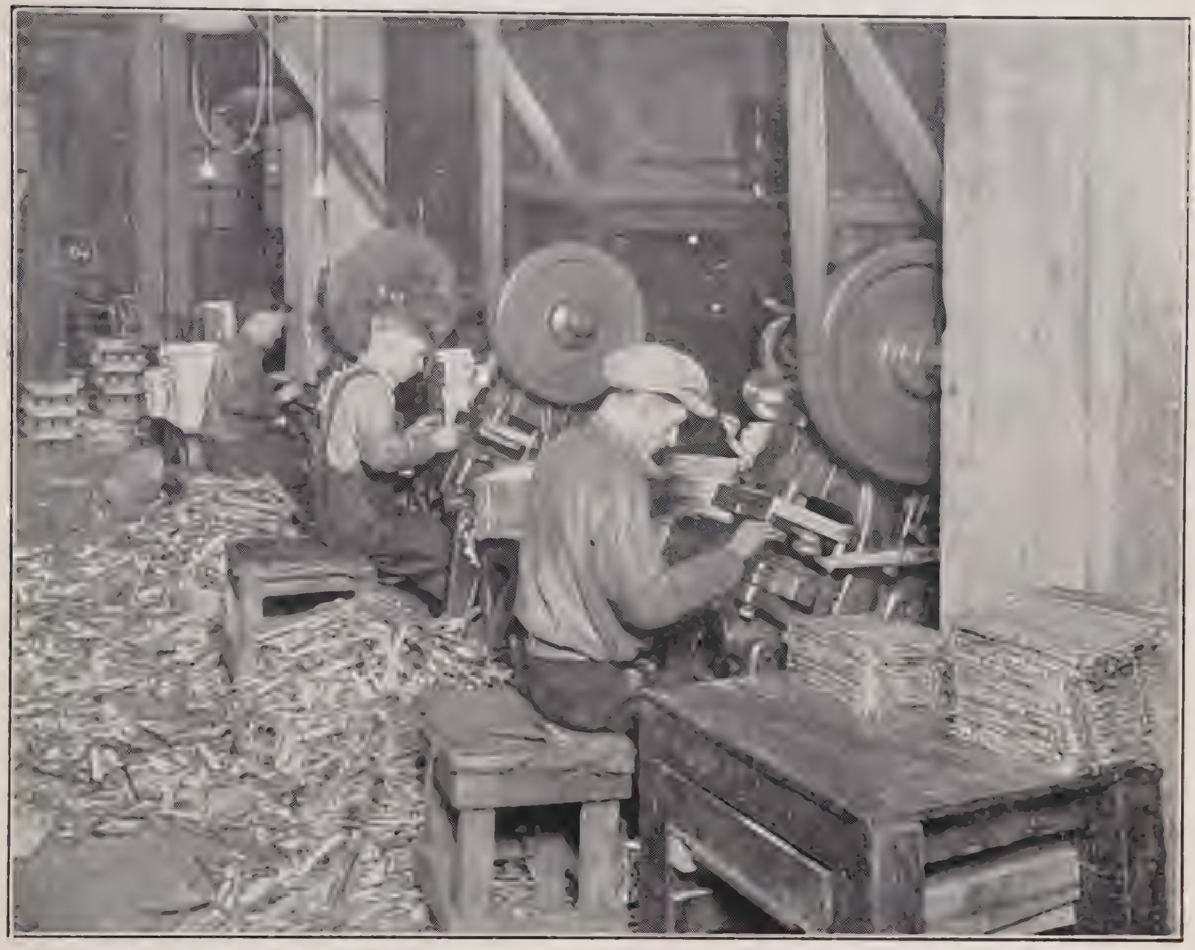


Figure 4—These Men are Trimming the Grids, After They have been Molded to the Correct Size and Shape. The Machines Press the Grids Flat, Form the Bars and Trim Off the Edges.

Other Gases Can Also be Used

It is also possible to use some of the newer oil gases, which are now being distributed by the oil and gasoline companies, compressed in cylinders. These gases are, in some instances, the product of the refinery and in others are casing head gases, taken directly from the wells. Some of them are commercial propane; others are marsh gas, and some are of varying content. Some of the lead burning of sheets for lining tanks, etc., is done where the portability of the gases is an important factor, and for this reason, it is often necessary to use gases compressed in cylinders. The amount of gas consumed, however, is so small that the cost of the gas is really not an important factor.

Preparation of Sheets

Seams between lead sheets may be flanged for welding, if desired, or as is usually the case, lapped from one-quarter to one-half inch. In the case of a lapped seam, it is usually customary to weld from both sides. When welding a flanged seam, lead welding rods are not required, because the flanges are fused down to make the weld. The lapped seam, however, requires the use of welding rods. In many instances when lining a tank with lead, it is impossible to get at the rear of the seam and in such cases, butt welds are superior to lap welds. These are prepared in identically the same manner as the edges of steel are prepared for a single vee joint. When making a butt joint, the edges are placed together and tack welded at intervals before the seam is fused.

In preparing all of these joints, it is essential, as heretofore stated, that the surfaces and edges of the sheets, as well as the welding rod, be absolutely clean of oxide; this can only be accomplished by scraping these surfaces far enough back from the seam to include an area the width of the puddle. In making a lap seam, it is necessary, of course, to scrape both sides of the sheet, so that where the two edges lap, there will be only clean, bright metal in contact. It is usually good practice to use a wooden mallet to tap gently along the seam, to be sure that the edges do actually contact and are not, in places, separated from each other.

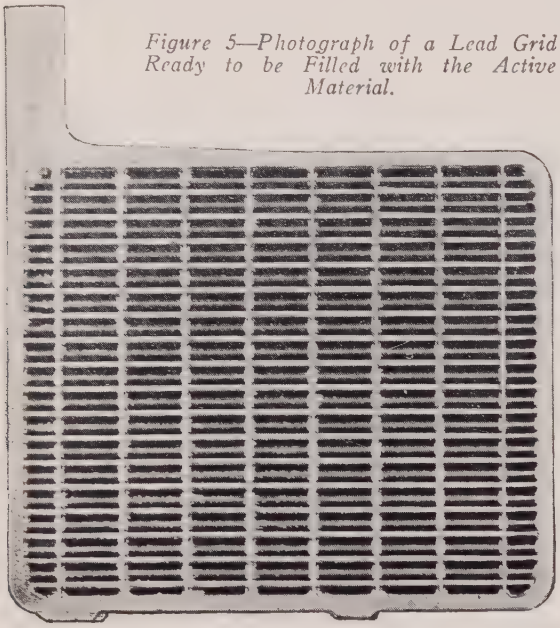


Figure 5—Photograph of a Lead Grid Ready to be Filled with the Active Material.

Welding Lead Seams

In welding the seam it is important that the welding rod and the lead sheets fuse at the same time; the position of the torch should be such that this will be accomplished. The torch should be held with the very small luminous cone of flame close to the metal, until it is fused. The torch must then be very rapidly moved, in order to prevent melting clear through the sheets. The seam is run rapidly, and quick, accurate manipulation of the torch is essential to produce good results. The motion consists principally in the close application of the flame momentarily and then its quick withdrawal; this is repeated as the puddle made by fusing the welding rods and sheets flows smoothly and evenly down the seam.

Figure 1 shows a lapped seam between two lead sheets. This sketch has been made, because this type of joint differs somewhat from others which have been shown previously in these lessons. The flanged joint and the single vee joint are not shown, because these joints are similar to the sketches in previous lessons.

Welding Lead Pipe

Lead pipe can be obtained commercially in the usual standard internal diameters and of various wall thicknesses. It is used extensively in chemical plants, paper mills and wherever the resistance of lead to the corrosive action of chemicals and acids is essential. Practice in welding lead pipe does not differ materially from the practice already described for the welding of steel pipe. The lead is easily cut and special fittings, like crosses, tees, Y branches, etc., can be very quickly cut with a hacksaw and other tools, and welded with a small lead burning torch. Some operators become so proficient in the use of the torch that these special fittings are welded in almost perfect alignment and the joints are fine examples of smooth, even, ripple welds.

The use of flanged joints is quite common in chemical plants and flanges may be welded to lead pipe quickly and easily. It is usually good practice to bevel the flange, or mold it, so that it will fit over the outside of the pipe with the bevel on the inside to facilitate welding. Special fittings may be made by rolling up sheet lead over suitable forms and welding the longitudinal seams. Flanges may be welded to the ends of these special pipes; or tees or branches may be made by cutting openings in the sides of the pipe and welding other pieces to the pipe. The practice is similar to that already described for the welding of steel pipe.

Welding Battery Terminals

The welding of the terminals of automobile storage batteries has become a very common operation in many shops throughout the country. The photographs of storage battery manufacture in this lesson, were taken with the idea of showing the student how storage batteries are made and to give him a better knowledge of the principles underlying their operation. While he may not have occasion to weld battery terminals on as large a scale as is shown by these photographs,

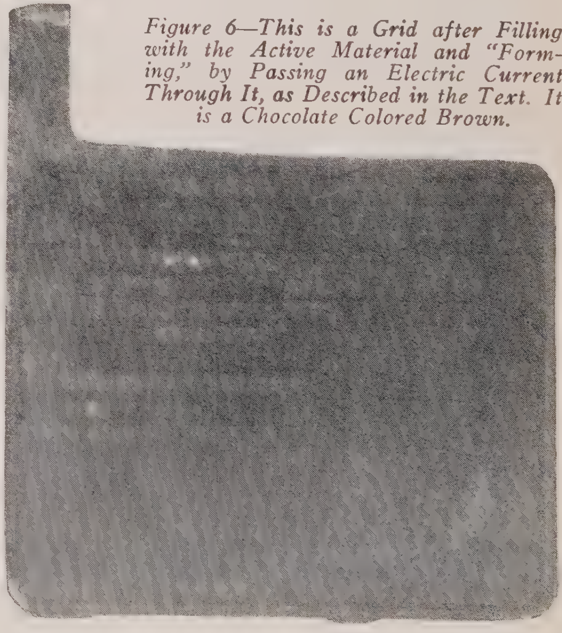


Figure 6—This is a Grid after Filling with the Active Material and "Forming," by Passing an Electric Current Through It, as Described in the Text. It is a Chocolate Colored Brown.

at the same time he should be familiar with this class of work, because in garages and welding shops in the smaller towns and villages, battery repairs may be made a profitable part of the business of the shop. The automobile storage battery, with which practically every one is familiar, at least in appearance, is the lead battery. Another type, the Edison alkaline battery, is occasionally used in some work.

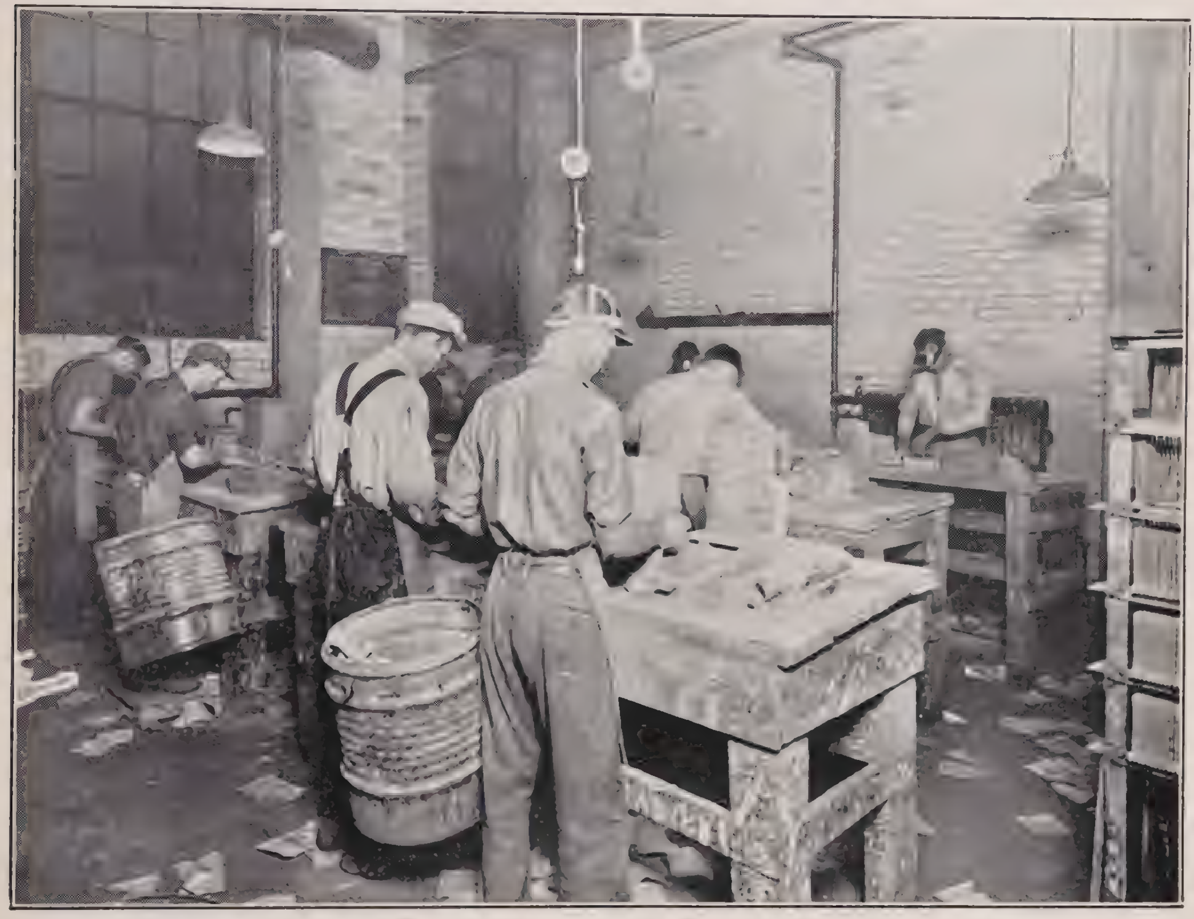


Figure 7—In this Photograph the Grids are being Filled with the Active Material, Which is Molded into the Grid Openings in the Form of a Paste. For the Positive Plate, the Active Material is Red Lead and for the Negative Plate, Litharge.

Lead Batteries

The lead battery, however, is the one which will be described in this lesson, as it will be the one the welder will encounter. It usually includes three cells, encased in a rubber container or box. Each cell consists of two lead electrodes made up of a number of plates, immersed in an electrolyte of dilute sulphuric acid. One of these electrodes is negative and the other positive. There is a chemical reaction which takes place resulting in a difference of electrical potential between the two series of plates, causing an electric current to flow between them. It is not necessary to discuss the theoretical side of batteries in too much detail, because their practical manufacture will be described and shown, so that any one can understand how they are made.

Lead Grids Are Molded, Pressed and Trimmed

The lead plates, which form the electrodes of each cell are molded with a large number of perforations through them and are called grids, before they are filled with certain chemicals. Figure 3 shows these grids being cast in the casting room of a battery manufacturing plant. Each of the men shown is casting grids in a casting machine. A mold is clamped in each machine. The man in the center foreground is pouring molten lead from a ladle into one of these molds. Piles of the cast grids are shown just in front of this machine, in the foreground of the picture and in the center background. The second step in the manufacture of these grids is to trim them to exact size. This is done upon the machines, shown in Figure 4. The three men in this picture are trimming grids rapidly, as indicated by the large piles of scrapped edges on the floor between them.

Each Battery Cell Has Either Eleven or Thirteen Plates

The majority of the batteries used have either eleven or thirteen plates to the cell. In the eleven plate battery there are six negative and five positive plates per cell, while in the thirteen plate battery, there are seven negative plates and six positive plates per cell. In all lead storage batteries of this type, using a liquid electrolyte, there is always one more negative plate than the number of positive plates. This construction is the result of the following peculiarity in plate action. When current is being discharged from a battery, the positive plates have a tendency to buckle away from the negative plates and it is, therefore, necessary to have one negative plate on each side of a positive plate. In this manner the tendency of the positive plate to buckle away from the negative plate next to it is counteracted by the resistance of the negative plate on its opposite side.

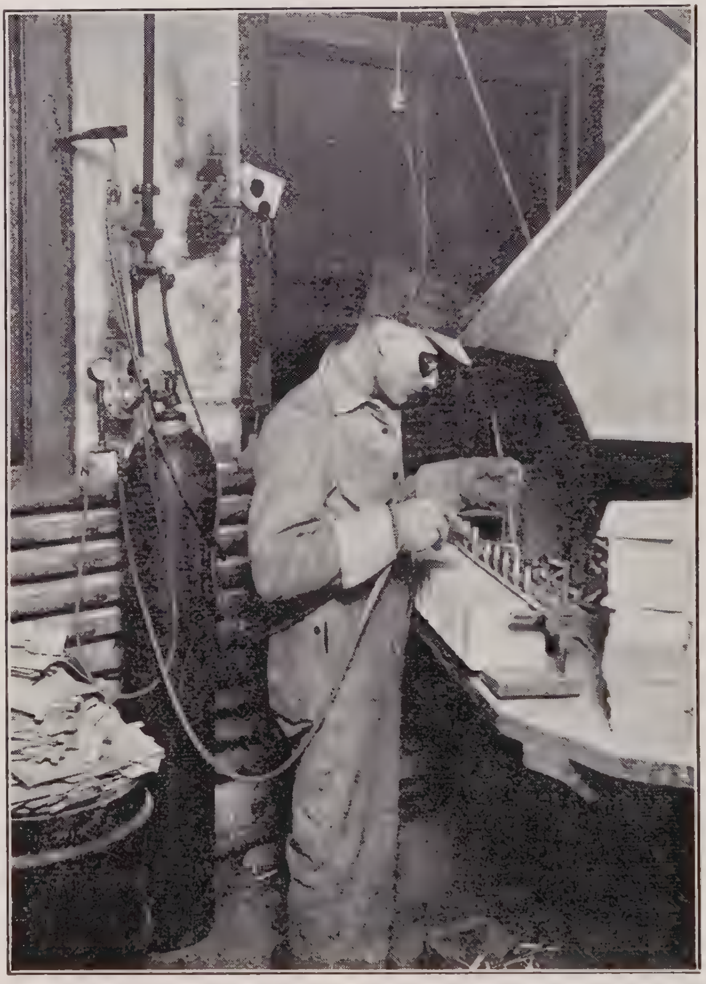


Figure 8—The Operator in this Photograph is Welding the Lead Terminals to the Plates. The Terminals are Cast to Fit Around the Plates to Simplify Welding and this Operation Requires Only a Few Seconds.

Voltage of Cells Not Dependent on Size of Plates

In most storage batteries there are three cells, each having a difference in electrical potential of approximately two volts. This difference in the voltage of the cell is not dependent on the size of the plate, but is the result of the chemical differences in the plates themselves. Perhaps, to make this clear, a few words about the principles upon which the battery operates will assist the reader to understand what this difference in potential means. A storage battery in its simple form consists of two plates, one positive and one negative, submerged in a jar containing dilute sulphuric acid, called the electrolyte. The plates contain finely ground lead, called the active material. This material is held in grids, or supports, which not only hold the material in place, but also serve as conductors for the current. As this active material is finely ground, or divided, it presents a very large surface to the electrolyte to enable the electro-chemical action to take place quickly and easily.

If the active material in each of the grids were the same, that is, pure lead, there would be no chemical difference between these plates and no current would flow. When an electrical current from an outside source, as for instance from a battery charger, is passed through the plates, the active material contained in the positive grid becomes highly oxidized, while the active material in the negative grid does not change. The active material and the positive plate become a brown chocolate color in appearance. The negative plate and the active material remain a light grey.

When the battery is fully charged, there is a distinct chemical difference between the active material in the positive plates and that in the negative plates, and this chemical difference causes an electrical difference, or potential, between the two poles of approximately two volts. When the poles of the battery are connected to a circuit, a current will discharge from the positive pole, through the circuit and back to the negative pole. As this discharge takes place, the positive plate slowly loses the oxygen in the active material and both plates become sulphated. If the discharge is carried far enough they will again become chemically alike and current will cease to flow.

When the battery is again charged with a battery charger, the current flows through the positive pole and plates to the negative plates and the sulphate of lead is driven off and the active material in the positive plate is again oxidized; the battery again becomes active. This cycle of operation can be continued until the plates are worn out.

Manufacturing Storage Batteries

In the actual manufacture of batteries, the process differs somewhat. Instead of placing pure, finely ground lead in the grids, and then charging the battery to change them chemically, the positive grid is filled, in the beginning, with a powder, commercially known as red lead, which is mixed with dilute sulphuric acid, and ammonium sulphate to prevent what is commonly termed shedding.

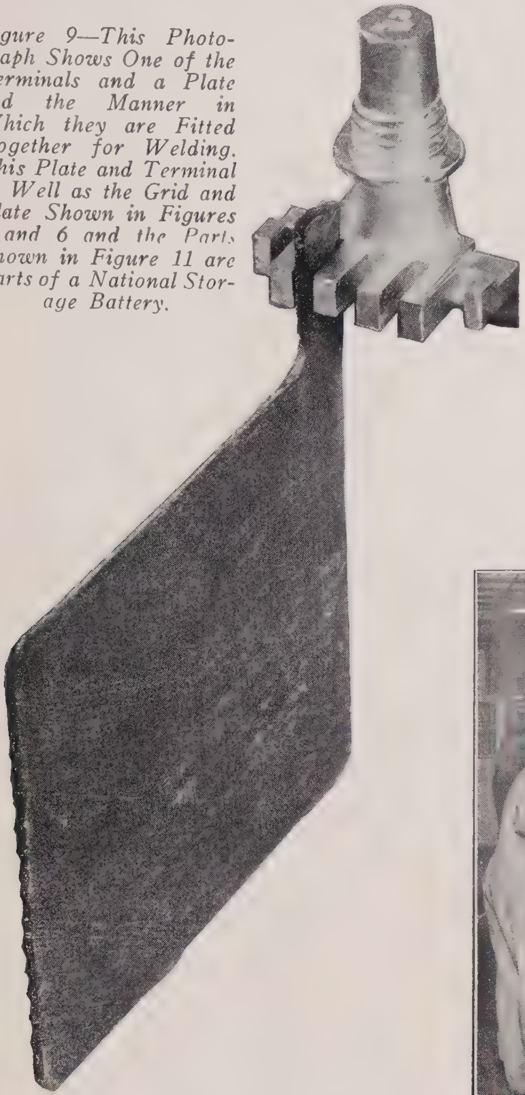


Figure 9—This Photograph Shows One of the Terminals and a Plate and the Manner in Which they are Fitted Together for Welding. This Plate and Terminal as Well as the Grid and Plate Shown in Figures 5 and 6 and the Parts Shown in Figure 11 are Parts of a National Storage Battery.

In Figure 7 men are shown filling the grids for batteries. The red lead for the positive grids mixed with acid is shown on the table in the foreground to the right of the operator. It is forced into the openings in the grids and smoothed down until even. The grids are then set in a rack to dry. A portion of this rack is shown to the extreme right of the photograph, Figure 7.

Filling the Negative Grids

The treatment of the negative plates, while mechanically the same is chemically different. The negative grids are filled with a paste, made of litharge and dilute sulphuric acid. Because of the contraction of litharge, when the paste dries, it is necessary to use what is called an expander to keep the active material from dropping out of the grid. This expander is usually barium sulphate. It may also be manganese sulphate, lamp black or graphite.

Forming the Plates

When the plates are thoroughly dry, they are subjected to what is called a "forming" operation. During this operation they are placed in a charging tank filled with a medium strength electrolyte, the positive and negative plates alternating, and being set with considerable space between them. The positive plates are connected to the positive current, while the negative plates are connected to the negative side of the circuit. Electricity, from the source of current, charges through the plates and the positive plates turn a dark chocolate brown in color, while the red lead changes to peroxide of lead. The negative plates during the same operation turn a dark grey

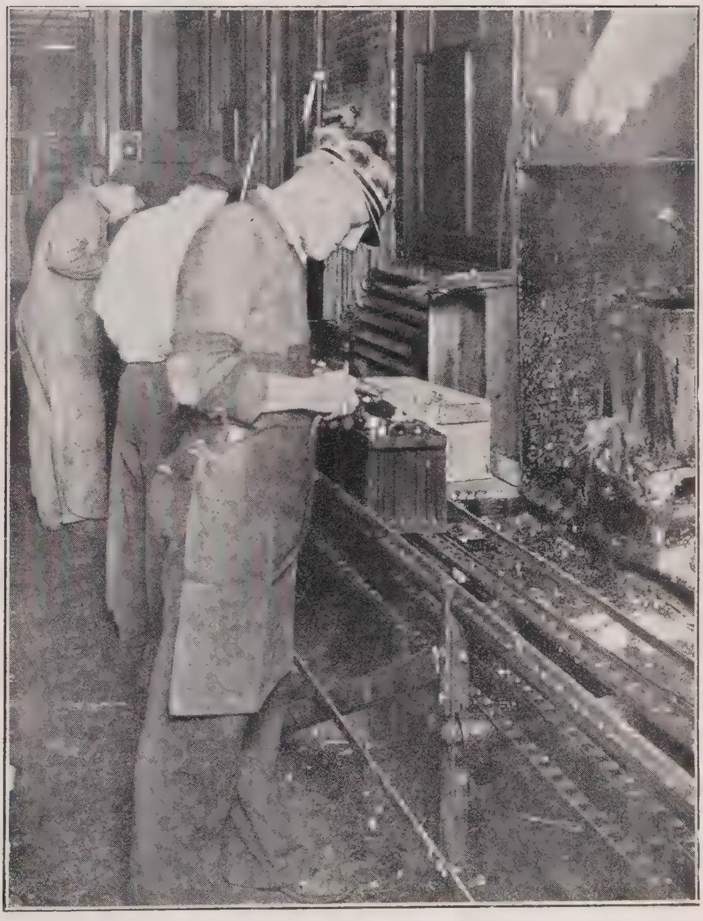


Figure 10—This is a Photograph of Several Operators Welding the Connectors to the Cell Terminals. The Batteries are Slid Along the Chain Rack Upon Rollers. A Photograph of a Terminal Post and a Connector is Shown in Figure 11.

color, because the litharge changes to a soft, spongy, porous, pure lead.

Welding the Terminals

The next step in the manufacture of these batteries is to connect the filled plates together with a terminal, so that the wires or leads, constituting the circuit of the car, can be connected to the positive and negative poles of the battery. The plates of the three cells are also connected together with suitable and permanent connections called connectors

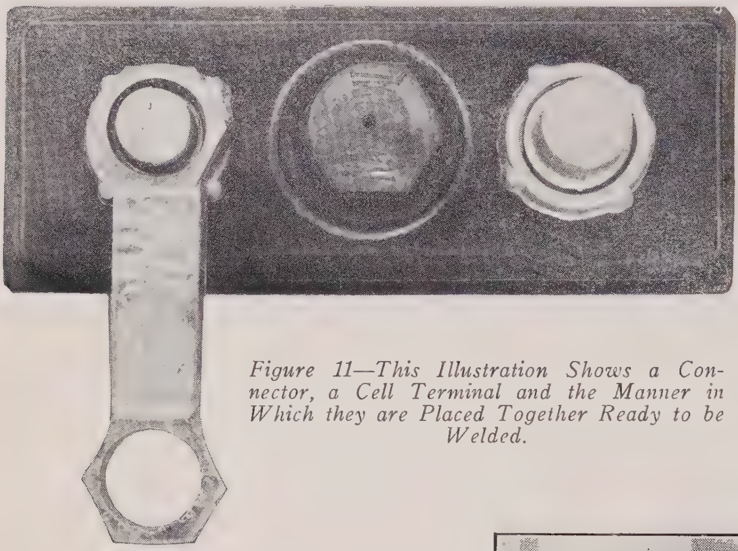


Figure 11—This Illustration Shows a Connector, a Cell Terminal and the Manner in Which they are Placed Together Ready to be Welded.

In Figure 8 a man is shown welding lead terminals to the plates with a small city gas and oxygen lead burning torch. The terminals are cast, so that their lower ends form a comb, the teeth of which, fit between the plates to facilitate welding. A photograph of one of these terminals is shown in Figure 9.

The plates are set in grooves in a wooden base, attached to which is a steel bar jig, to hold the plates in their correct alignment, and to enable the operator to set the terminals in correct relation with the plates before welding. This is a very simple rack and is shown in sufficient detail in Figure 8. The actual work of welding a terminal to the plates requires only a few seconds time and is easily and quickly accomplished. It does require, however, skill on the part of the operator in handling the torch to prevent melting the edges of the plates, or the terminal and having the lead run away.

In the shop where the photographs were taken, oxygen and city gas are used exclusively for this work. In other shops some other gases may be preferred, depending upon the location of the plant and the availability of the gases. In some battery shops hydrogen and oxygen are used exclusively for this work.

Welding the Connectors

The plates are set in a hard rubber box, divided into three compartments, each constituting a cell. Between the plates, specially treated, grooved pieces of wood are placed, called separators. These prevent the plates from touching each other and causing a short circuit of the cells.

When the plates have been assembled into the battery box, together with the separators and other parts, it is necessary to connect the positive and the negative poles of each cell together, and this is done with a lead link called a connector. The terminals of the cells project upward from the top of

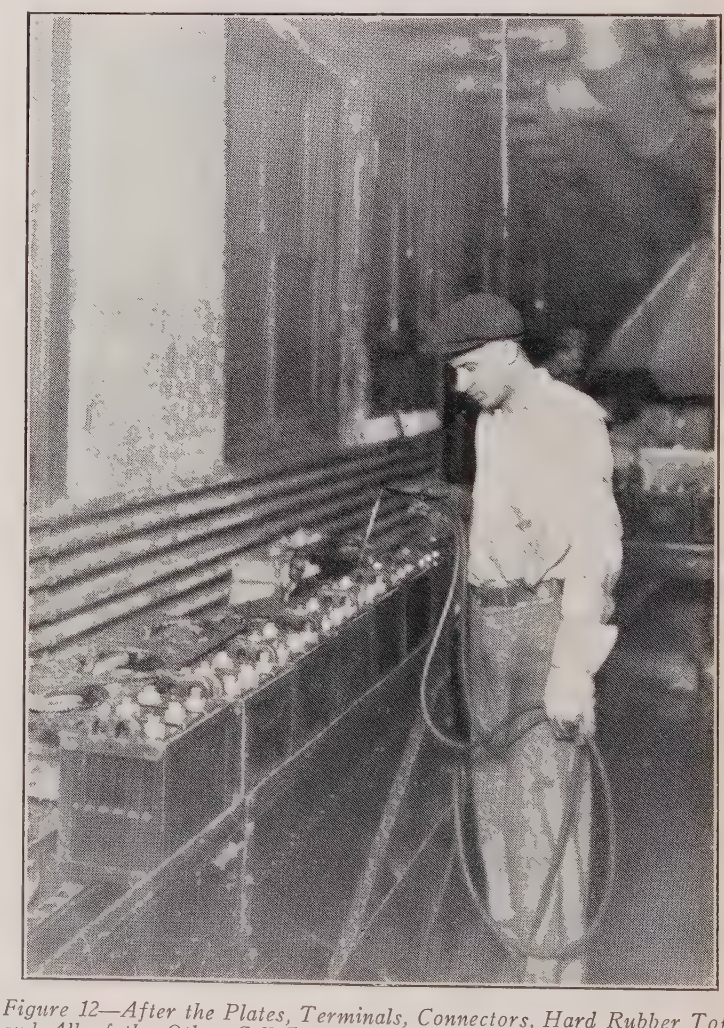


Figure 12—After the Plates, Terminals, Connectors, Hard Rubber Tops and All of the Other Cell Parts are Assembled, the Battery is Sealed with Tar. This is Done with a Torch, as Indicated in this Photograph.

the battery, like posts, and the connectors are slipped over these posts and welded into one piece. The process is simple. Operators are shown in Figure 10 welding these connectors, as the batteries are passed by them on a rack. In Figure 11 a photograph of one of these connectors and the terminals from the cells is shown.

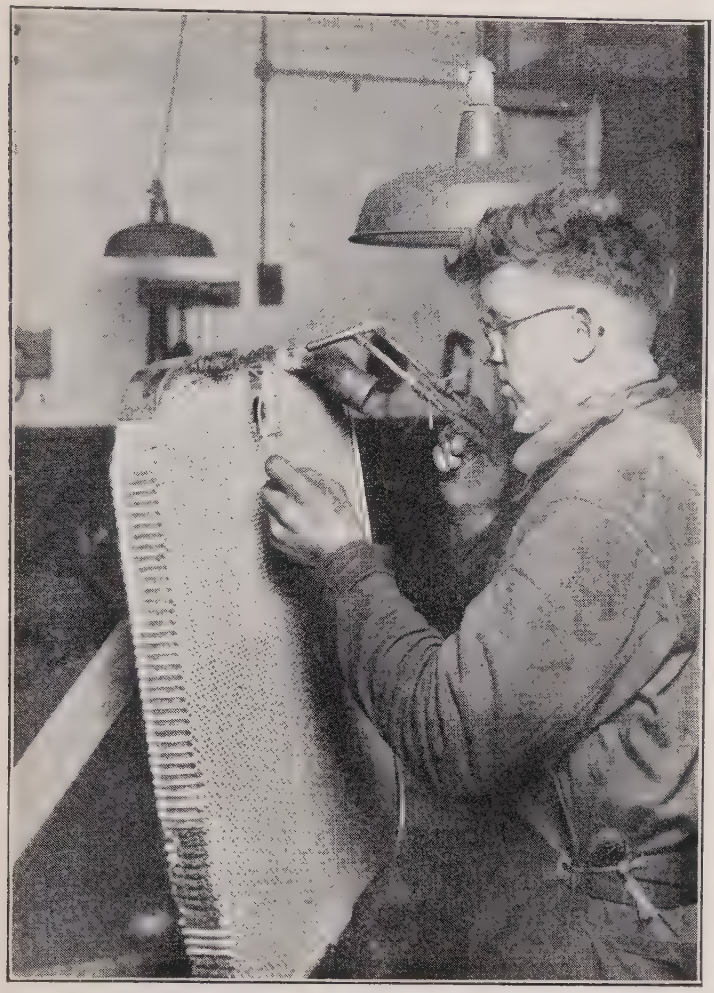


Figure 13—Photograph Showing an Operator Soldering an Old Tank to a New Honeycomb Core of an Automobile Radiator. The Core is a Cleverly made up Assembly of Formed Brass Sheets in Which no Tubes are Used. The Shell is Placed Over the Top of the Core and Soldered all the Way Around to Make it Water Tight.

The top of the battery is completely sealed with tar, after the filler openings of the cells have been put in place and all other parts have been assembled. The final sealing is done with a torch, as shown in Figure 12.

Composition of Battery Electrolyte

The majority of batteries used consist of either eleven or thirteen plates per cell and have capacities of from eighty to one hundred ampere hours. The electrolyte used consists of one part of chemically pure sulphuric acid, mixed with two and one-half parts of chemically pure water. The specific gravity of the battery electrolyte when the battery is fully charged is between 1.275 and 1.300. When the battery is discharged its specific gravity is between 1.120 and 1.150.

Soldering Automobile Radiators

The soldering of automobile radiators is a job which can be included in the regular work of the welding shop, and in the smaller towns, where there are no radiator shops specializing in this kind of work, it can be made profitable. The construction of automobile radiators varies considerably with the different cars, and there are, of course, many types of radiators in use. Some of these are built up with vertical tubes, running up and down the radiator, built into thin sheet brass grids, constituting a net work, or core. The water passes downward through the tubes and the air circulates around the tubes passing through the openings in the core.

Honeycomb Type

There are other types of radiators in which there are no tubes. One of these, which is in common use today, is called the honeycomb type. This radiator core is built entirely of sheet brass, cleverly formed and shaped, until it has the appearance of a large honeycomb. The vertical water passages, downward through this honeycomb, are formed in the brass itself, and the entire structure is dipped in soft solder, to hold the joints together and make them leak-proof.

Figure 13 shows an operator soldering a new honeycomb type radiator core to an old tank. This tank

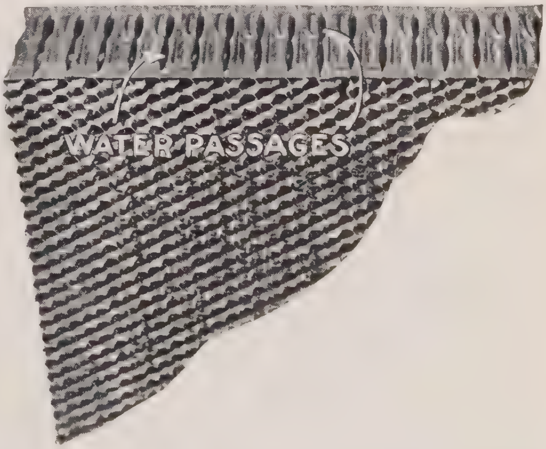


Figure 14—A Radiator Core of the Honeycomb Type. There are No Tubes Used in This Type of Core. The Water Passages are Formed by a Clever Method of Pressing and Assembling the Brass Plates.

is so constructed that it fits over the end of the core where the water passages enter.

The soldered seams, then, must be continuous all the way around the edges of this tank, where it joins the top surface of the core. The job, however, is a simple job of soft soldering and does not differ from any other soft solder work, except that a torch is used instead of a soldering iron. In Figure 13 the operator is working with what is commonly called a city gas and air torch. Compressed air and city gas are used; the Bunsen burner flame is sufficiently hot for this class of work. There is very little body of metal as the tank at the top is made of light pressed brass and the radiator core is entirely of light sheet brass. When the shell is soldered all around the radiator core, an air pressure of fifteen pounds per square inch is placed upon the water passages and the shell is submerged in a tank to detect any leaks, due to imperfect soldering. Figure 14 shows details of the construction of the radiator core, so that the manner in which the formed plates, or sheets of brass are assembled will be clear. Figure 15 illustrates the radiator tanks.

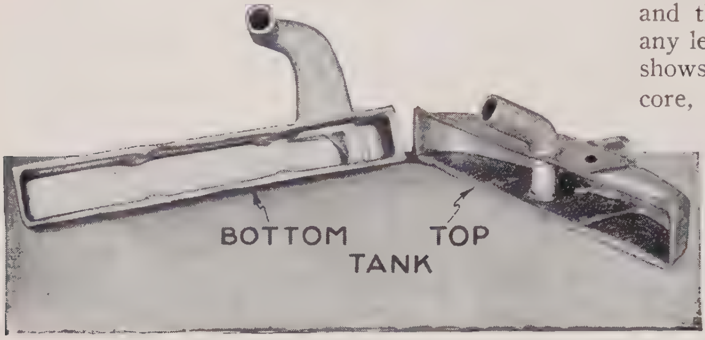


Figure 15—The Top and Bottom Tanks which are Soldered to the Core.

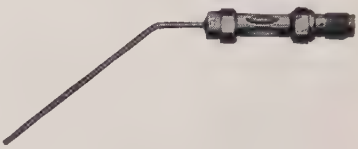


Figure 16—A Radiator Soldering Tip for Use With an Oxy-Acetylene Torch. This Tip is Small Enough to Enter the Openings of the Radiator; With Flux and Some Wire Solder a Repair can be Quickly Made.

A Manufacturing and Repair Shop

Figure 17 shows a view in the radiator shop of United Motors Service, Inc. The man in the foreground is fitting a new core, of the honeycomb type, into a radiator frame. The man in

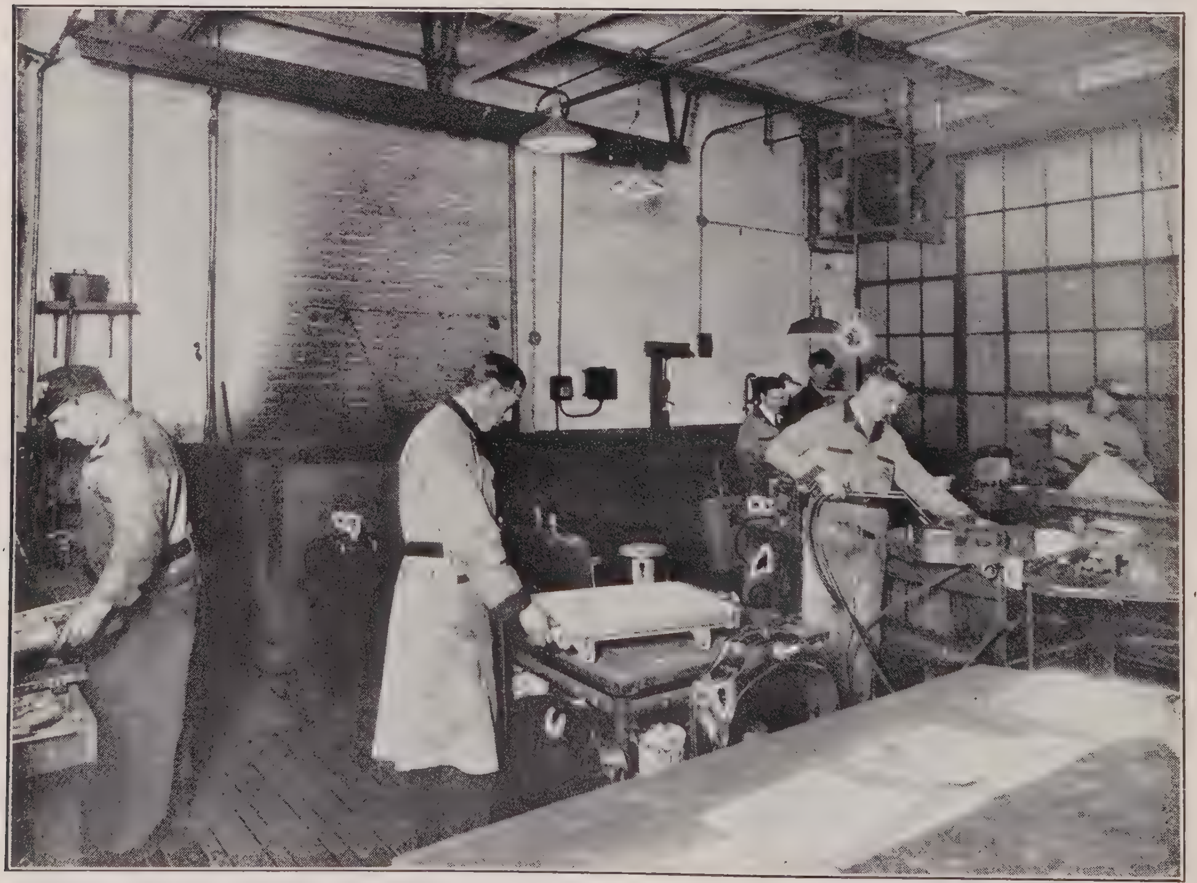


Figure 17—This is a View in the Radiator Department of United Motors Service, Inc., Minneapolis. The Various Operations in the Manufacture of Radiators and the Repair of Old Radiators are Shown in This Illustration.

the middle foreground is using a torch to solder a tank to a core, and the man in the rear of the shop is soldering a brass liner to the core with a soldering iron.

It will be appreciated that extensive use of soft soldering is required for the manufacture of automobile radiators and the work requires soldering skill. Leaks often occur in the honeycomb openings, caused by accidents, or blows of some kind which have been delivered to the front of the automobile. In some instances the chafing of the bolts holding a winter front will cause the radiator to leak. In such cases a torch is used having a long tip and a very small flame. This torch can be passed into the core through the openings and, if skillfully used, the leak repaired with soft solder.

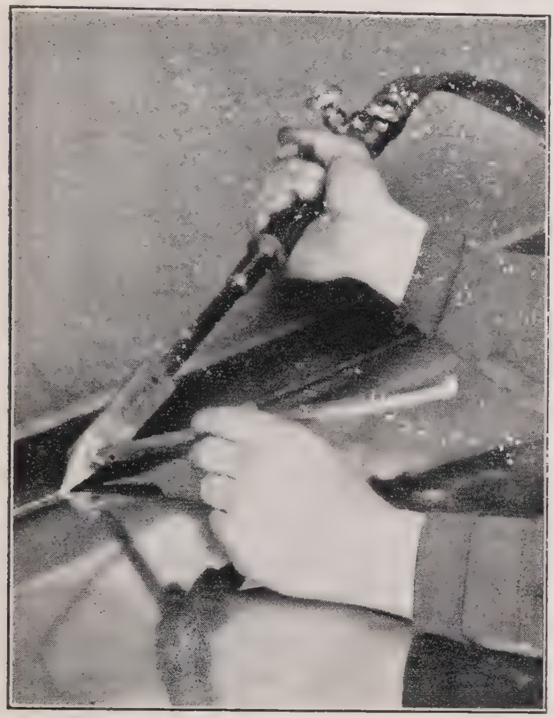


Figure 18—An Oxy-Acetylene Soldering Iron in Operation on a Long Seam.

Soft Soldering

The welder should know something about the use of a soldering iron, a small oxygen and acetylene radiator torch, or a city gas and air torch, if he is to accomplish good radiator repairs. It is impossible in this lesson to give more than a few simple directions with reference to soft soldering, but the subject is very well covered in a book entitled "Soldering and Brazing," by James F. Hobart. Soldering irons are made with many shaped copper bits, now usually heated with a gasoline torch, or a city gas and air Bunsen burner in a small furnace. Electric soldering irons are commonly known; there are also soldering irons having oxy-acetylene burners incorporated in the bits, which are used extensively, particularly where other gases are not available. In some instances irons are arranged, so that the soldering bit is made, like a tip, to fit into the handle of an oxy-acetylene torch. Such an iron is illustrated in Figure 18.

Good Tinning Essential

One of the most essential requirements of soldering with an iron is proper tinning of the point of the copper, and an excellent method to accomplish this purpose is given by Mr. Hobart as follows: A soft brick is obtained and the top surface of this brick is roughened slightly with a cold chisel. Some of the brick dust is left on top of the brick and a large piece of rosin and a lump of solder are melted along the top surface of the brick in a path which would be followed by rubbing the copper on top of the brick. The copper is then cleaned of all oxide by filing off the end of the bit. It is heated to the proper temperature and rubbed on the brick until thoroughly coated with tin, or "tinned," as a workman terms the process.

A hot soldering copper will oxidize very rapidly and it is difficult to tin the clean surface without exposing it to the air, thus forming another film of oxide. The use of the brick, however, takes advantage of its roughness and the rubbing of the copper on this rough surface in a bath of melted rosin and solder keeps the surface bright and at the same time excludes the air during the cleaning operation.

When a copper is properly tinned, the surface to be soldered is cleaned and suitably coated with flux, the soldering operation becomes a very simple one. The temperature of the iron is important and it must be maintained just at the right heat, but this degree of heat will be quickly recognized after a little practice.

Soldering Solutions and Pastes

Soldering solutions are made of both raw and cut muriatic and hydrochloric acids. Soldering compounds are made from rosin, salammoniac, zinc oxide, soda, etc. There are, of course, many prepared solutions and pastes upon the market, which give satisfactory results. So that the student will have some knowledge of the solutions and fluxes used, the following general description is given: Raw muriatic or hydrochloric acid is made by placing a small quantity of the acid in a cup or a dish and adding pure water, preferably rain water or distilled water, in the proportion of approximately one part of water to three parts of acid. Commercial muriatic and hydrochloric acids are solutions of gas in water. Hydrochloric acid, when pure, is a very dense gas, which throws off heavy fumes when exposed to air.

Raw hydrochloric acid, as just described, is used extensively for soldering galvanized iron and zinc. Cut acid, which is the common name for a solution of zinc chloride, is made by placing the diluted hydrochloric acid in a cup, or glass jar, and adding, piece by piece, small quantities of clean zinc. As the zinc is placed in the acid there is heating, a boiling of acid, and bubbles rise from the surface. Zinc should be added until all bubbling ceases. As the reaction produces hydrogen, which is inflammable, mixing the solution should be done out of doors. The acid should then be strained through several thicknesses of cloth and the solution is ready for use.

Rosin Fluxes

Powdered rosin of itself makes good flux for brass and tin. Rosin, salammoniac and soda may be mixed together with oil to form a paste if desired. Salammoniac is a good flux for copper. As far as the welder is concerned in the average shop, he will probably purchase a soldering compound already mixed which will answer his purpose for most of the soldering work he has to do.

Solders

There are a large number of soldering alloys upon the market. The various grades of common solder consist of different proportions of tin and lead. Coarse solder, as it is often called, has a larger percentage of lead and less of tin and is used for rough work. Fine solder contains more tin and less lead, and is used for joints where greater strength is required. The ordinary common solder, which is encountered is usually half and half solder, as it is called, that is, solder containing one part of tin to one part of lead.

The melting point of lead is approximately 620 degrees, while that of tin is approximately 450 degrees. The melting temperature of the one to one lead and tin alloy is given by some authorities as being 466 degrees.

Job Sheet No. 18

Welding Lead Sheet

The student should procure for the work in this job sheet a supply of seven pound lead sheet. This is the commercial lead sheet about one-eighth inch in thickness. This lead should be cut into strips one and one-half inches wide and approximately six inches long. A portion of this lead should also be cut into strips one-quarter inch wide and twelve to fourteen inches long. These narrow strips will be used as filler rods.

The student should use the smallest sized tip available for his regular torch, or better yet, one of the specially designed lead burning, or airplane type torches. If too large a tip is used, the student will have considerable difficulty in controlling the melting and the flowing of the lead. Besides the torch the student will, of course, need the standard set of regulators, hose and cylinders.

The type of joint to be made is that shown in Figure 1, called a "lapped joint." This is the joint that is most commonly used in the manufacture of lead tanks, or other articles made of lead sheeting.

After the regulators, hose and torch have been connected and the proper sized tip placed in the torch handle, the pieces of lead should be prepared for welding. This is done by scraping the edges and the surfaces of the pieces of lead with a sharp instrument, such as a bearing scraper, until all of the oxide has been removed. After the pieces have been well scraped, they should be placed with the edges overlapping, as shown in Figure 1. The next step is to scrape one of the narrow strips, which are to be used as a filler rod, on all surfaces until the lead is bright and clean. After this has been done, the torch may be lighted and the actual welding begun. The student will, in all probability, have a good deal of difficulty, at first, in regulating the amount of heat applied to the lead, so that a hole is not melted completely through the sheet. However, after several attempts, he will learn that it is necessary, especially on light weight sheeting, to hold the torch so that the flame points almost parallel with the top of the seam. The welding of the seam should be carried out in the manner already described in the text.

In case the welder is troubled with the forming of a coat of oxide upon the surface of the lead to be welded, he may easily eliminate the formation of this oxide by applying a thin film of grease, oil or vaseline to the surfaces of the lead immediately after they have been scraped bright. This coating of grease or oil prevents air from coming in contact with the lead and will remain upon the lead until burned up by the flame of the torch. This treatment of the surfaces may occasionally be particularly valuable, when it is desired that the weld have a bright, clean appearance.

Questions:

1. What is lead burning?
2. How should lead sheets be prepared for welding?
3. What is a lapped weld?
4. How are the plates in a storage battery cell connected together?
5. How are the honeycomb type of automobile radiators made?
6. With what tool are leaks in the center of a radiator core occasionally repaired?
7. How may the surfaces of lead sheets be kept from oxidizing after they have been scraped bright, but before they have been welded?
8. Why is a soldering solution or soldering acid used when soft soldering?
9. Is it always necessary to use a soldering copper when soft soldering?
10. Describe one method of tinning a soldering copper.

Lesson No. 19

Jobs For The Job Shop

SINCE the time Lesson No. 1 was written many suggestions have been received from men familiar with this course of instruction with reference to certain jobs which in their opinion, should be included in the course. Many of these jobs were interesting and instructive and would, without doubt, be of value to the welder. It was believed that some of them really should become a part of the course; all of them could not be published in a book of this size. Lesson No. 19 was, therefore, given its title "Jobs for the Job Shop," and in this lesson are assembled a few jobs which have not been given prominence in other lessons and which, it is believed, will be a valuable addition to the course.

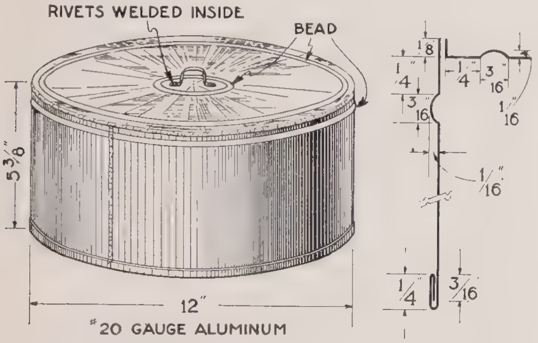


Figure 1—An Aluminum Steam Table Plate Cover. The Sectional View to the Right of This Sketch Shows the Manner in Which the Sheets of Aluminum Were Placed Together and Flanged at the Edges of the Circular Seam to Facilitate Welding. If Sheets of Aluminum Were Available, Which Might Otherwise Be Scrapped, the Manufacture of Such Covers Might Be a Profitable Job for a Shop. The Joints Could Be Ground and Polished, to Make the Seam as Smooth as Possible.

Welding Aluminum Steam Table Covers

Circular aluminum covers are used to a large extent to cover the dishes of food, which are placed upon steam tables in cafeterias, restaurants and hotel kitchens. These covers are made of light sheet aluminum, and the principal requirement is that they are steam-tight and have a joint which will not collect particles of food and thus may be kept clean.

Welded joints fulfill these requirements to better advantage than any other type of joint. Of course, these covers could be spun from one piece of aluminum, but the cost of the spinning and the expense of the dies and tools used for this purpose would probably exceed the cost of welded joints. A welded cover can be made of two pieces of sheet aluminum; one a circular disc representing the top, and the other a strip of sheet aluminum, sufficiently wide and long to permit rolling to the circumference of the straight side of the cover. The cover is shown in Figure 1, and the sketch to the right of this figure indicates the method of flanging the side and the cover pieces to facilitate welding. Welding sheet aluminum vessels of this kind is a simple operation, providing a suitable jig is available. With-

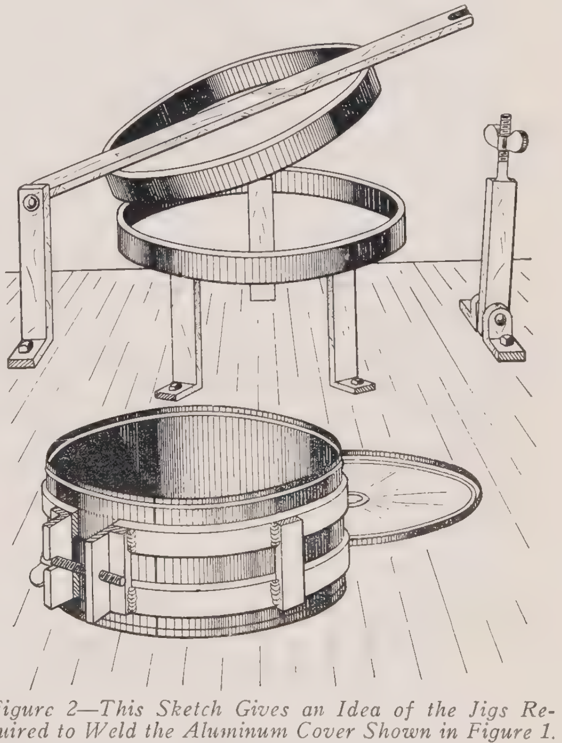


Figure 2—This Sketch Gives an Idea of the Jigs Required to Weld the Aluminum Cover Shown in Figure 1. The Details of Construction Are, of Course, Not as They Would Be in the Final Design, and the Jigs Would Vary with the Requirements of the Shop, Making Them Up. They Would Have to Be Strong Enough to Withstand Constant Use. It Should Be Possible to Assemble the Sheets in Them and Remove the Finished Product Quickly and Conveniently.

out jigs, the job is likely to warp and buckle and the result will be unsatisfactory, but with jigs, in which the plates can be quickly assembled and held rigidly, little difficulty will be found in making a good weld. A suggested jig for accomplishing this purpose is shown in Figure 2. It consists of a ring of steel, supported by three supports, upon which the cover will rest and around which the circular side will fit. Another ring, of the same diameter, is arranged to fit over the top of the cover and hold it down securely during the welding operation. This ring is attached to a lever and a hinge, so that a clamp will hold it in place. The circular side is held in alignment with a band screwed tight with a thumb screw. The side seam should be welded first; then the flanged edges around the top of the cover may be fused together.

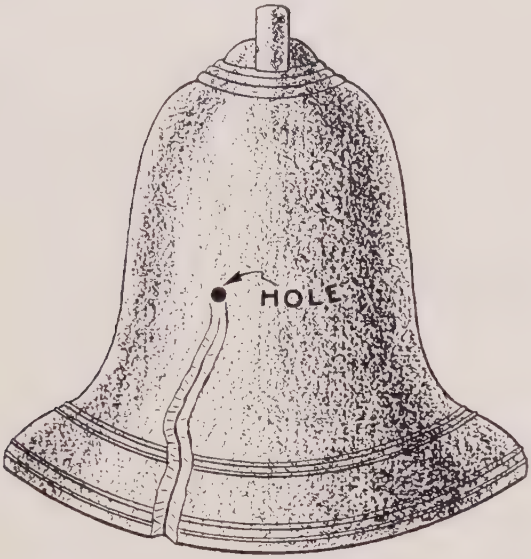


Figure 3—A Bronze Bell Prepared for Welding. A Hole Should Be Drilled Through the Bronze About Three-Quarters of an Inch Beyond the Apparent End of the Crack, and in Line with It. This Hole will Prevent the Extension of the Crack Further Into the Bell, When Preheated. The Edges of the Crack Should Be Bevelled by Grinding or Chipping to an Included Angle of Ninety Degrees. The Practice in Preparing and Preheating a Bell Is Identical with the Method for Iron Castings.

These jigs, as shown in Figure 2 are, of course, but roughly sketched to give the idea. A detailed drawing of the jigs would show them designed in accordance with good mechanical practice. Different shops would vary the details of such a jig to meet their particular requirements. While no great pressure is required, such a jig must be built strongly enough to withstand continued use, and as convenient as possible for assembly of the sheets and removal of the completed cover.

Welding a Bronze Bell

Most welding shops have been, at some time in their experience, requested to weld a bronze bell. Some of these jobs are small bells which have been cracked; others are church bells, or school house bells, which are considerably larger. The problem is much the same, whether the bell is small or large, but, of course, the degree of preheating and the type of preheating fire used would depend much upon the size of the bell.

Bells are made, as a rule, of what is known as bell metal. This alloy often consists of seventy-eight per cent of copper and twenty-two per cent of tin. There are other combinations of tin and copper, used for different types of bells, in which the tin content ranges all the way from fifteen per cent to twenty-five per cent. The standard bell metal, containing twenty-two per cent of tin, is quite brittle and difficult to machine. The tin content controls the brittleness of the metal and the pitch of the note; the higher the tin content, the higher the pitch. Bells sometimes crack after continued use, the result of a severe blow of the clapper; or they may be broken by dropping them during erection, or in transportation. As a rule, however, the breaks which the average welding shop will be called upon to repair are cracks, extending from part way up the bell downward to its edge. This is the simplest type of break to repair.

Preparing the Metal

The inner end of the crack should be located as closely as possible with a small magnifying glass and a hole drilled about three-quarters of an inch beyond the end of the crack and in line with it. The hole is drilled beyond the end of the crack and not at the point where the end appears to be, because it is very difficult to locate the exact end of the crack, and the object is to drill the hole through solid metal. This will prevent the crack from extending beyond the hole. The bell metal should then be ground or chipped away from each side of the crack until a groove, or vee, having an included angle of ninety degrees is formed.

Some bell metal alloys are so hard that chipping is impossible; in such cases the bevel must be ground with a flexible shaft grinding wheel. The bronze may be so hard that it cannot be ground, or a grinding wheel may not be available. In such cases, the welder has no alternative except to melt through to the bottom of the crack during welding. On thin sections of the bell this can be done, but on heavy sections it will be difficult. If chipping is possible, the chips should be saved to be melted into the groove during welding. These chips should be placed in a box of some kind, where they are readily accessible when needed.

Welding Rods and Flux

Before proceeding with the job, it is necessary to secure some suitable welding rods. Following the general principles laid down in these lessons with reference to alloys, it is obvious that the welding rods used for this work should be made of bell metal; that is, metal having a tin and a copper content nearly equal to that of the bell metal in the bell. This exact analysis, of course, is unknown to the welder. The tin content of the bell may be fifteen per cent, or it may be twenty-five per cent. If he can go to the nearest brass foundry and have some welding rods cast from bell metal, this would be the best procedure, but it might consume the profits which he expects from the repair of the bell.

It is always desirable, in welding bronze, that the rod contain a small amount of phosphorus. Some authorities recommend in addition to the phosphorus very small amounts of aluminum. These rods should be cast rods, because where the tin content is as high as it is in bell metal, the alloy cannot be drawn into wire.

As far as is known, welding rods to fulfill all these requirements are not usually available to the average welding shop, but the shop can sometimes procure bell metal rods made by a local foundry which usually must substitute, together with the chips of bell metal, from the edges of the crack.

A good flux is also necessary. An excellent flux, which is recommended for welding bronze by Granjon and Rosenberg in A Practical Manual of Autogenous Welding*, is made as follows: Equal parts of borax glass, table salt and boracic acid powder are mixed together. This white flux powder is sprinkled on the hot metal and the hot welding rod is dipped into it from time to time.

The presence of small quantities of phosphorus in the rod assists in eliminating oxidation and decreases absorption of gases. It also forms a film of slag over the molten metal, which prevents its contact with the air. Traces of aluminum in the rod, if present, also decrease the absorption of gases.

Preheating

It is, of course, necessary to preheat a bell to a medium cherry red, the temperature of which is about 1250 degrees. This can be done by building a firebrick furnace around the bell and heating with charcoal, as already described for welding iron castings. The practice insofar as preheating is concerned is identical with that for cast iron. The bell should be placed in the preheating furnace in such manner that it is well supported underneath the weld with asbestos cement or carbon putty, because bronze when close to a red heat, is weak and will collapse.

Welding Procedure

The welding procedure for bronze does not differ materially from that described for bronze welding various metals. The welding rod should be dipped in the flux, and applied to the metal just before it begins to melt. Just before melting, bright globules of tin appear on the surface of the bronze; at this moment the welding rod should be applied. The luminous cone of the flame should not be brought in contact with the bronze at all. Welding should be done with the envelope of the flame developing the heat required.

It should not be thought by the welder, however, that the welding of bronze is a brazing process. It is not brazing, but, in fact, fusion welding; that is, the bronze pieces being welded and the bronze welding rods are all thoroughly melted together. Remelting the bronze after it has been once melted is bad practice because the weld should be built up to its final surface as it progresses.

Reheating After Welding

When welding has been completed, the charcoal fire should be replenished and the bell reheated to a dull red and allowed to cool until stone cold as the fire dies out. The practice in this respect is identical with that for iron castings.

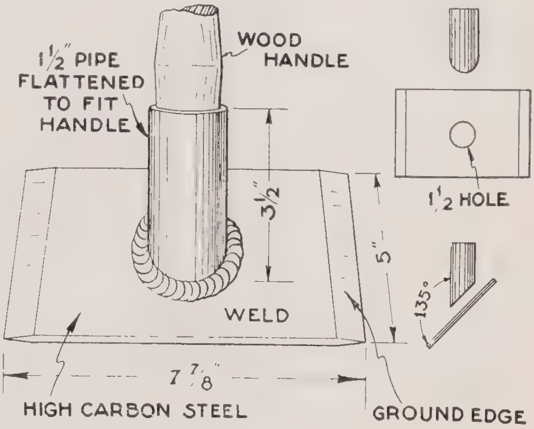


Figure 4—A Convenient Brush Ax. This Ax Is Used to Cut Down Brush and Is Swung in the Same Manner as a Golf Stick. The Blade Is Made of High Carbon Steel and the Handle Extends from the Blade at an Angle of Forty-Five Degrees. It Is a Very Convenient Tool in the Woods.

When the repair is made in this manner, the bell will ring with a tone similar to its original one which in most instances will be close enough for all practical purposes.

Welding Bronzes in General

Brasses are alloys of zinc and copper; bronzes are alloys of tin and copper. The general procedure given above for the welding of a bronze bell can be utilized for welding almost all bronzes. The principal point to be borne in mind is the fact that the welding rod used must closely approximate in percentage of tin and copper the piece to be welded. The flux suggested for welding bells will work to good advantage for all bronzes. For those bronzes which are not too high in tin, the phosphor bronze welding rods mentioned on page 164 will be found excellent.

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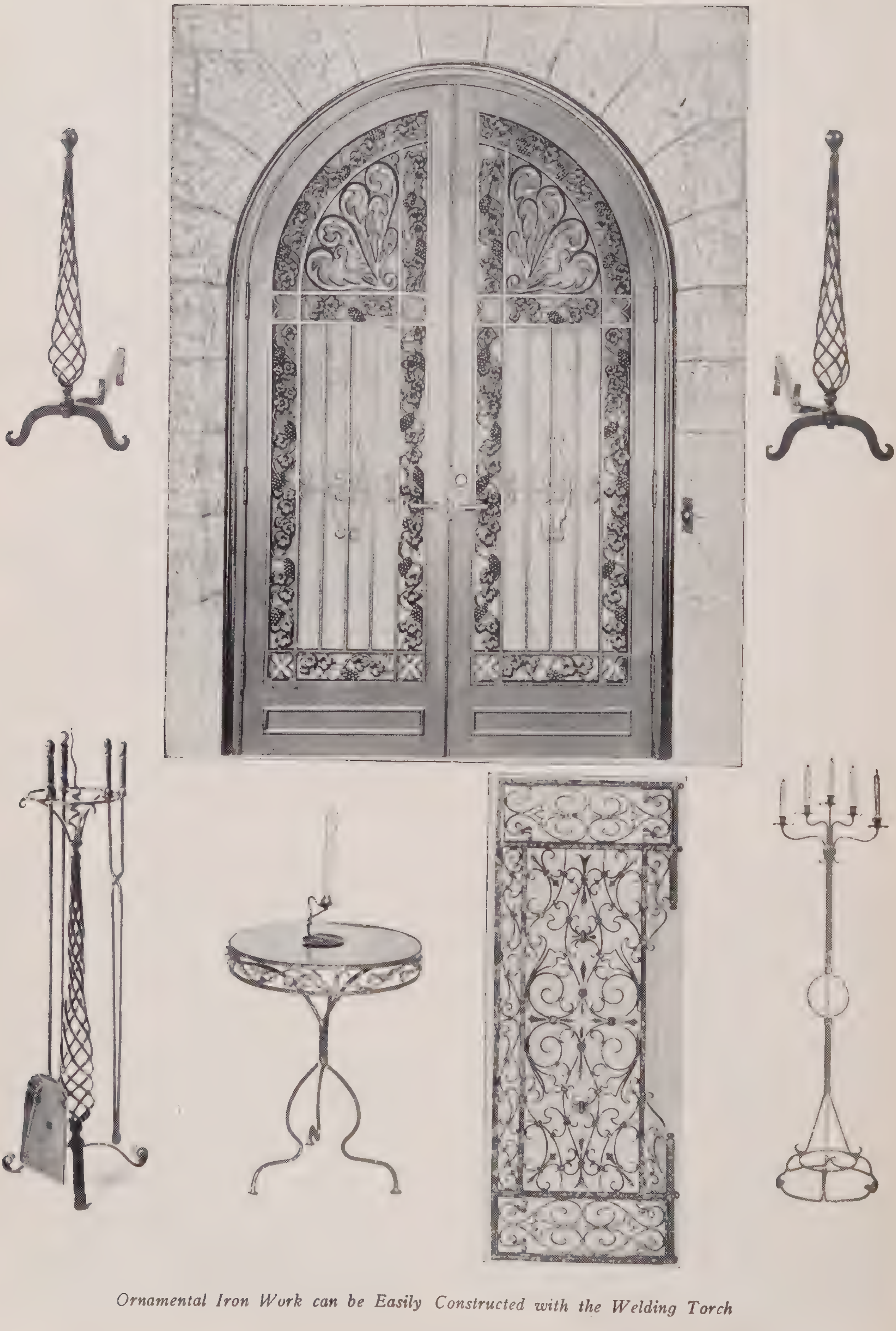
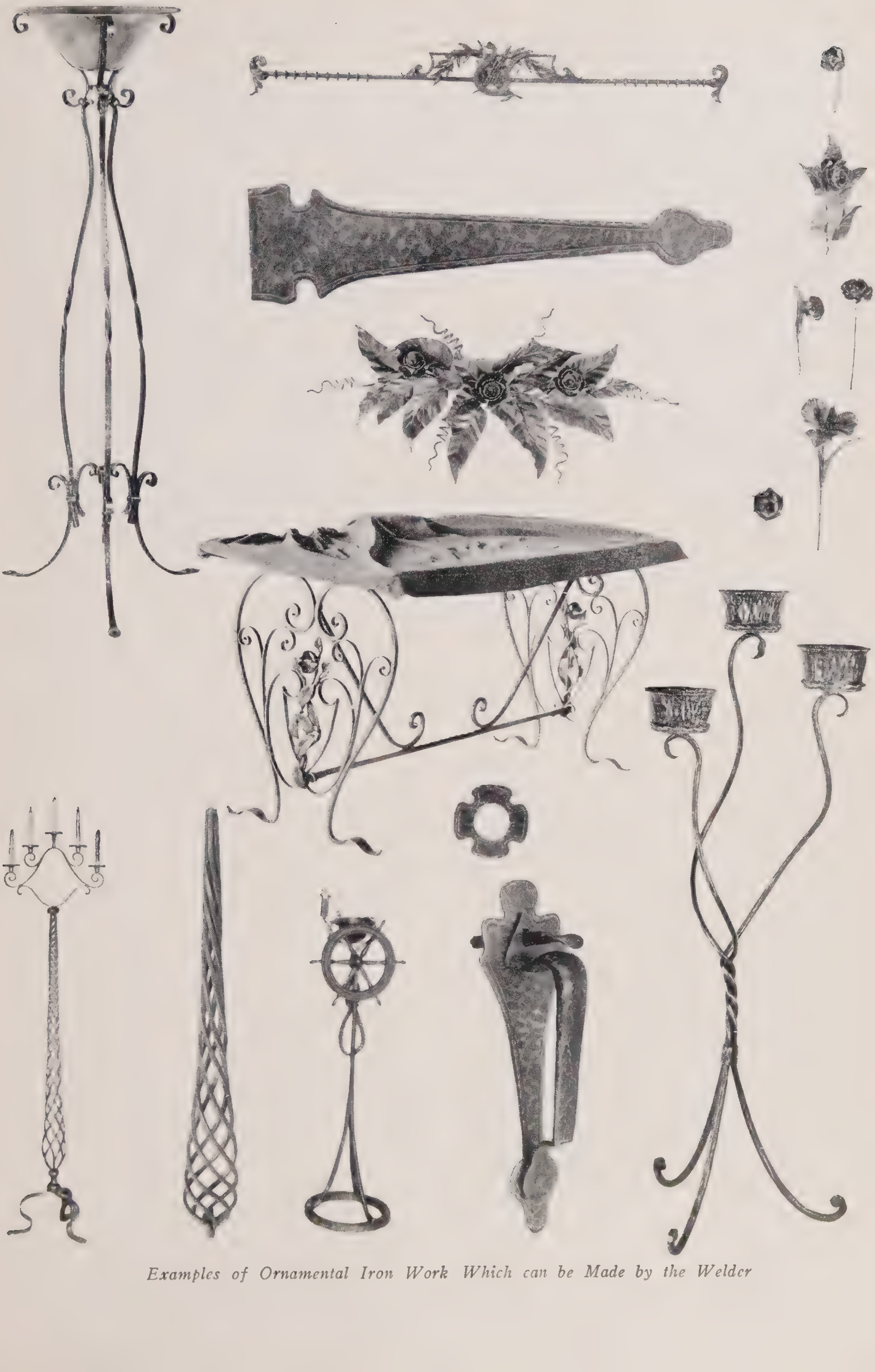
* *Published by Charles Griffin and Company, Limited, London, England.*



Ornamental Iron Work can be Easily Constructed with the Welding Torch



Examples of Ornamental Iron Work Which can be Made by the Welder

Welding a Brush Axe

A very handy tool which can be used to good advantage for cutting down brush is illustrated in Figure 4. This tool can be made up by a welding shop in spare time and sold at a profit. The blade is a piece of high carbon steel seven and seven-eighths inches in length and five inches in width. A one and one-half inch hole is cut in the center and a piece of one and one-half inch pipe, three and one-half inches long on the long side, is cut with one end at an angle of forty-five degrees. This pipe may be cut with a hack-saw, or it may be cut with the cutting torch after being marked with the center templet of templet sheet No. 5, page 73. The piece of one and one-half inch pipe is flattened to fit the wood handle, and is then welded to the high carbon steel blade. In welding the pipe to the high carbon steel, a low carbon welding rod should be used, similar to welding rod No. 1, page 155. The high carbon steel should be heated just to the point of fusion, but great care should be taken not to burn it. By proper manipulation of the rod and the torch, the edges of the weld in the high carbon blade can be "tinned" with the low carbon rod and the weld built up upon this tinned surface.

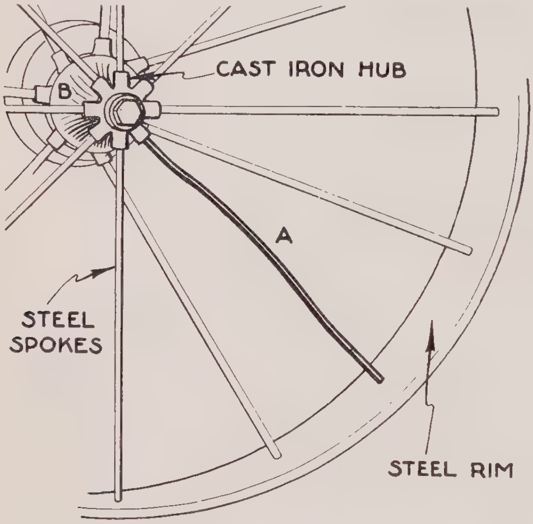


Figure 5—This Sketch Shows a Farm Implement Wheel, Having a Cast Iron Hub, Steel Spokes and a Steel Rim. One of the Spokes Has Broken Away from the Hub. It Has Been Bent to Compensate for the Contraction Which Will Take Place After a Bronze Weld Has Been Made Between the Spoke and the Hub.

Welding Farm Implement Wheels

A job which frequently comes into the welding shop for repair, particularly in agricultural districts, is a broken farm implement wheel. These wheels are often made with steel rims, steel spokes and cast iron hubs. The spokes are usually riveted to the rim and cast into the cast iron hub at the time the hub is made. Sometimes a malleable iron ring on each side of the hub is used to protect the cast iron from excessive strains.

Wheels made in this manner are light, strong and substantial, but sometimes the spokes break loose from the hub. A repair of this kind is easily and quickly made, but the welder must consider the effect of heat upon a spoke and the contour of the rim, before he attempts welding. Suppose, for instance, that the spoke "A" has broken away from the hub "B," in Figure 5. The object is to weld the spoke "A" into the hub "B" with as little distortion of the wheel as possible. If the spoke "A" were heated and expanded, the expansion would naturally push the rim out of shape. If the spoke were heated only and no additional metal were welded to it, it is quite likely that contraction, as the spoke cooled, would draw the rim back into place.

When, however, a fusion weld is made, additional metal is usually added, and the expansion is so great that the soft metal of the weld is upset or pushed out sidewise. When the metal cools the contraction usually results in a shorter spoke and distortion of the rim. In the case of the wheel in Figure 5 the spoke "A" is free to slip in the hole in the hub "B" and a very simple way to accomplish the repair is slightly to bend the spoke "A" out of alignment, as indicated. It is then possible to bronze weld the steel spoke to the cast iron hub. Expansion, as the spoke and hub are heated, will cause the spoke to slip further into the hole in the hub "B." Contraction, as the bronze weld cools down, will tend to straighten the bend made in the spoke and will not distort the rim. This is a very simple operation and the principle underlying it will be readily understood if a little study is given Figure 5.

Another way in which this weld can be made is to cut through the rim around the spoke where it is riveted, to free entirely the spoke from the rim. The spoke may then be bronze welded to the hub "B" and, as it is free to expand and contract through the hole in the rim, the rim will not be distorted. After the bronze weld has been made between the spoke and the hub, the other end of the spoke may be quickly welded to the rim and the distortion of the rim will be very slight. The weld between the spoke and the rim, however, should not be made until the bronze weld between the spoke and the hub has become cold. There are, of course, other methods which will produce the same results but these will depend entirely upon the location of the breaks and the amount of welding which is necessary. If the welder will consider the entire job, using the reasoning which has been given in these few paragraphs, he will be able to work out any problem of this kind.

Using Soft Solder to Smooth Up Dents and Welds in Automobile Bodies and Fenders

Dents are often caused by accidents to automobile bodies where it is extremely difficult to bend the steel back again to its former contour. This is often the case where the inside of the steel panel is not accessible, and again where, on account of upholstery or other fixtures of the car, there is no way to make a support against which to pound out the dents. Under such circumstances the dents can be filled in with soft solder, to make a smooth exterior surface, the contour of which is the same as the steel body was before the surface was dented. This surface can be painted over and the repair will pass unnoticed.

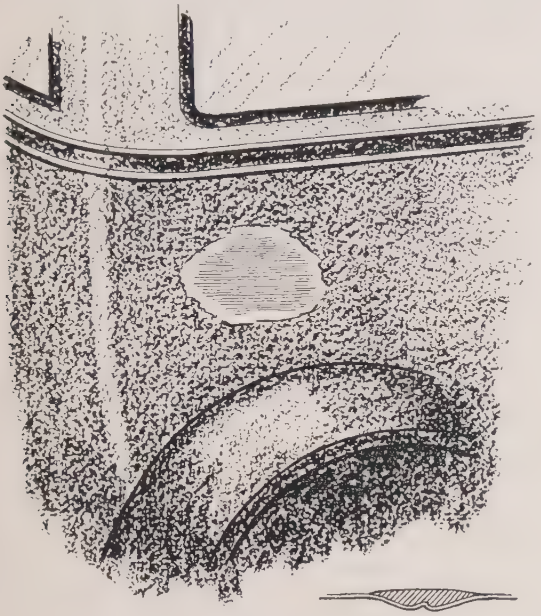


Figure 6—Sketch Showing a Dent in an Automobile Body Which Has Been Filled in with Solder. The Small Sectional View Below Shows a Cross-Section Through the Dent to Indicate the Depth of the Solder Which Has Been Filled In.

The soldering operation requires some skill on the part of the operator, but skill can be acquired after a little practice and the repair will not be found difficult. The dent may be as deep as one-half inch or it may be quite shallow. It may extend over a considerable area, or be just a sharp depression, perhaps no more than an inch square. In making a repair of this kind, the first operation is thoroughly to clean the paint away from the surface of the metal, extending about three-quarters of an inch beyond the edges of the dent. This can be done with a portable, motor driven wire brush, or with emery cloth, until the metal is perfectly clean.

A grade of solder, which will produce satisfactory results, is made of one part of tin to two and one-third parts of lead. The melting point of this solder is slightly higher than the melting point of the common grade of solder, known as half and half, in which there is one part of tin to one part of lead. The melting temperature of solder made of one part of tin to two and one-third parts of lead is about 478 degrees, while the melting point of the one to one grade of solder is approximately 466 degrees.

An oxy-acetylene torch will provide the heat, and it is necessary to have a hard wood trowel, with a handle attached, as illustrated in Figure 7. Such a trowel can be very quickly made from an old shoe blackening brush, to which a rectangular piece of hardwood has been attached. The daubing-brush end of the improvised trowel may be used to apply oil when necessary. A cleaning flux will be required and raw muriatic acid will answer this purpose. Muriatic acid cut with zinc will be found excellent for the soldering operation, or any good prepared soldering flux can be used. A dent in the body of a car is usually in a vertical position and for this reason more dexterity is required in the handling of the solder than would be the case if it were to be applied horizontally. After the surface has been thoroughly cleaned, it should be heated slightly with the torch, the raw muriatic acid applied and the surface rubbed to prepare it for tinning. The torch should now be used and the metal heated until the solder will melt when the stick of solder is rubbed over the steel. The solder can then be evenly spread with a piece of cloth. Tinning in this manner should cover the entire surface and beyond the edges of the dent about one-half inch.

A can of medium cylinder oil should be available and the trowel should be kept immersed in this oil. When ready to fill in the dent with solder, after tinning has been completed, the surface should be heated until more than enough solder to fill the dent has been made to adhere in a lump to the center of the tinned surface. This can be done by manipulating the torch and the stick of solder at the same time. It is then necessary to lay down the stick of solder and pick up the wood trowel from the can of oil. The large piece of solder adhering to the center should be heated with the torch until plastic. The torch should then be quickly removed and the trowel used to spread the soft solder, or smooth it out, over the tinned surface until the dent is completely filled.

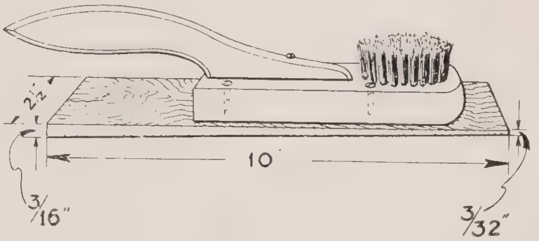


Figure 7—Sketch Showing a Hardwood Trowel Made from an Old Blacking Brush and a Rectangular Piece of Hardwood.

The solder will adhere to that portion of the surface which has been tinned, but it will not adhere to untinned areas and if it has been spread out too far over an untinned surface, it should be removed immediately. Additional oil may be used during smoothing, applied with the daubing brush. This will prevent the trowel from sticking. In using the torch only the envelope of the flame should come in contact with the metal, or the solder. The luminous cone should never be brought too close to the work, because it is too hot and will burn the solder. When the surface has once been tinned, care must be taken not to overheat it during the soldering operation. The steel must not be heated at any time more than just enough to flow the solder over it. A little practice will enable the welder to do an excellent job. In the same manner welds to fenders and bodies, which are rough can be smoothed up to present a better finish. It is good practice to add to the thickness of the metal in this manner rather than to file down the rough parts of the weld which decreases the thickness of the metal at the edges.

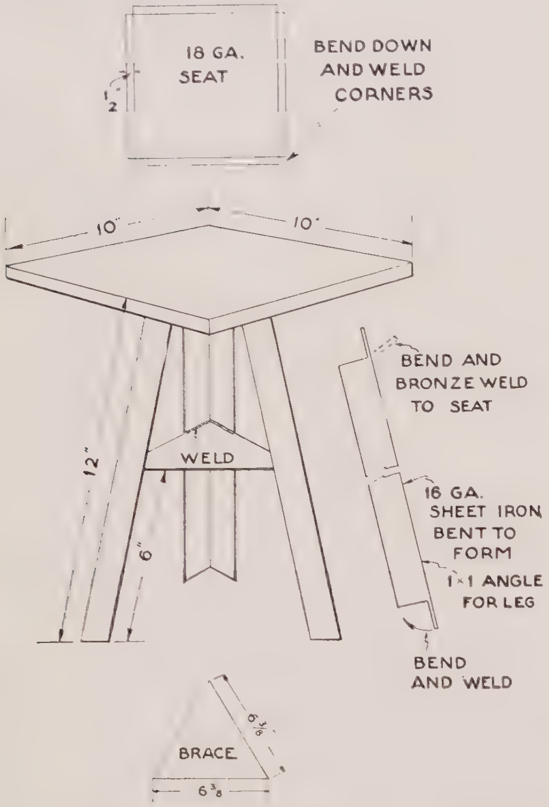


Figure 8—A Milking Stool Made of Sheet Steel with All Joints Welded.

The soldered surface over the dent can be finished up by filing with a vixen file, which has been dipped in turpentine. A little turpentine spread on the surface of the solder will also assist the operation and when the surface is perfectly smooth, it can be painted the color of the car and the repair will scarcely be noticeable.

Welded Stools

Strong, serviceable stools can be made by welding pieces of sheet steel together, which would otherwise be scrapped. Some of these stools can be made low, not exceeding twelve inches in height, to be used for milking stools. Others can be made higher for use at a work bench. Stools can be designed in many ways to suit the purposes for which they are intended. The legs can be made from light angle iron, if desired, or they can be made by cutting strips of No. 16 guage sheet steel to the correct length and bending them in a bending break, if one is available, or if not, over the edge of a bar or plate until the two surfaces are at right angles.

An excellent milking stool can be made as shown in Figure 8. A piece of sheet steel, about No. 16 guage in thickness, and eleven inches square, is used for the top of the stool. The corners are cut out, as shown in the small sketch, to permit one-half inch of each side of the top to be bent downward and welded at the corners. The legs are made, approximately twelve inches in length, of No. 16 guage steel strips, two inches in width, bent to a right angle to form angle irons. One side of the end of each leg is bent over to close the end of the angle iron, as indicated in Figure 8, and welded to the other leg. This is done to prevent the ends of the legs resting on the floor from being sharp and cutting into the floor. At the opposite ends, the legs may be welded to the seat of the stool to better advantage when constructed as shown. The stiffening bracket midway between the seat and the leg ends, is a triangular piece of sheet steel welded to the legs. In this manner a rigid, serviceable stool is made entirely from sheet steel.

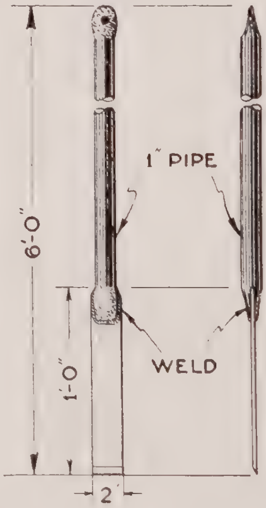


Figure 9—An Ice Chisel Made of a Piece of One Inch Pipe Welded to a Part of a Spring Leaf from an Automobile.

Ice Chisels

In the northern part of the United States and Canada, and along the Great Lakes, fishing through the ice is a pastime or a business for many men. Off the port of Buffalo, ice fishing, on a considerable scale, is carried on every winter and this is true of many other lake cities. In order to cut holes through the ice, some sort of a chisel is required.

A very convenient and serviceable tool of this kind is illustrated in Figure 9. This chisel is made from a piece of one inch pipe welded to a piece of a spring leaf from an old Ford car. The leaf of the spring is cut off with the cutting torch and inserted into a slot cut in the end of the pipe. The joint is then welded securely, as described for the welding of the brush axe. The end of the spring leaf is then ground to a cutting edge after the temper has been drawn until the edge is soft enough to file. A hole is usually cut in the opposite end of the pipe, through which a rope may be inserted, to prevent losing the chisel through the ice.

Welded Ornamental Iron Work

Ornamental iron work presents a very great field for welding. Every one is, of course, familiar with ornamental iron gates, fences, grills, window flower-boxes, railings, etc. These are usually made of forged iron bars and parts, which are bent and formed to a decorative design, making handsome ornamental structures. Before the extensive use of welding, many of these parts were fastened together with countersunk screws. The drilling and tapping of the holes and the fitting of the parts, so that this mechanical method of building them together could be used, was difficult and expensive.

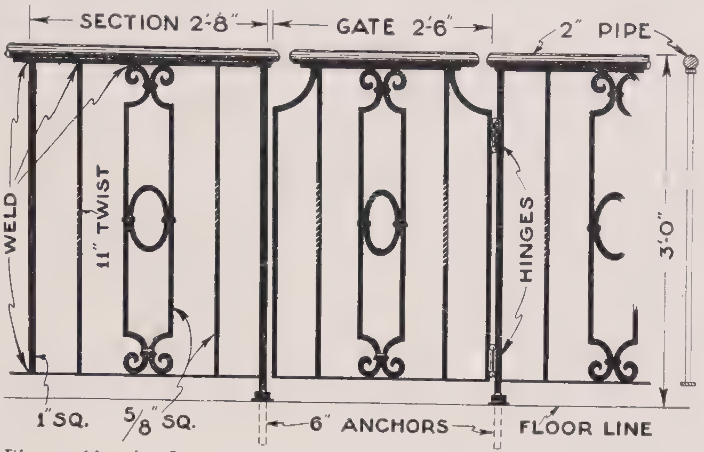


Figure 10—An Ornamental Iron Office Rail, Together with a Gate. The Parts of the Ornamental Iron Work Have Been Welded Together.

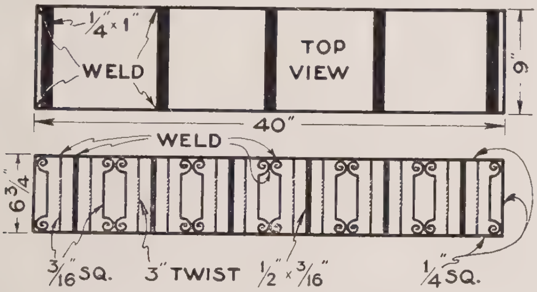


Figure 11—An Ornamental Iron Window Box. A Box of This Type Is Far More Decorative Than a Wooden Flower Box Would Be and It Is Permanent.

With the oxy-acetylene torch, it is a very simple matter to weld parts of ornamental iron work together quickly, conveniently and at low cost. Almost any structure, no matter how intricate the design, can be assembled without the use of screws, bolts, or rivets. There is no reason to describe the details of this work, because welding is the simple welding of steel parts. The suggestion to the welding shop is that ornamental iron work may afford the shop a field for welding, which will enable the shop superintendent to keep his men very busy in the production of saleable articles of this kind. Figures 10 and 11 are detailed sketches of a welded ornamental iron rail and a welded ornamental iron window-box. There are hundreds of designs for such pieces, and the shop superintendent's own ingenuity may provide variations to suit his particular requirements.

Welded Supports or Horses Made of Scrap Pieces of Pipe

Scrap pieces of pipe may be extensively used by making all kinds of structures, which are useful. In the repair of automobiles, it is often necessary to jack up the car, and to place a temporary support under the axle, thus releasing the jack, while the repair work is being done. Some quickly made and inexpensive supports of this kind are welded from pieces of scrap iron, and are illustrated in Figure 12. This support is generally similar in outline to a common wood saw-horse. Of course, it is much lower and is made of short pieces of pipe welded together.

Larger and longer pieces of pipe may be used to make larger horses to support sheet steel in a factory or warehouse, or to be used as supports for angle iron, channels, I-beams, etc., which are being fabricated. In the country districts, farm gates and fence posts can be made in this manner. In manufacturing plants, guard rails for machinery, and all sorts of structures, can be made from scrap pipe. In the oil fields, where scrap pipe is available in considerable quantities, the frames of buildings, supporting towers for tanks and many other structures are made of pipe which could not be otherwise used.

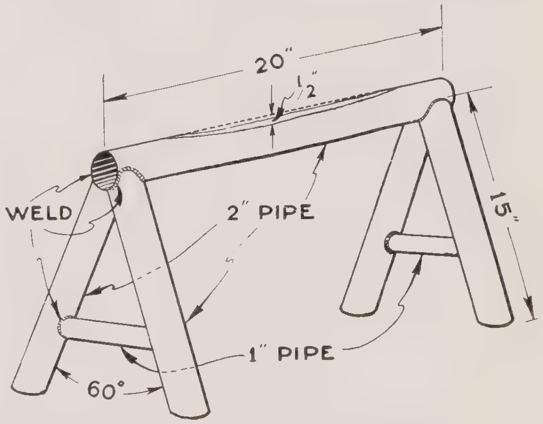


Figure 12—Supports for Automobiles Made of Scrap Pieces of Pipe Welded Together. The Supporting Pipe Is Bent Slightly as Indicated to Prevent the Axle of the Car from Slipping Off the Support.

Job Sheet No. 19

Welding Bronze

By this time the student has had the opportunity to try his hand at welding many different types of metal, with the exception of bronze. This job sheet is, therefore, devoted to the welding together of two pieces of cast bronze.

Because of the great number of different shapes into which bronze is cast, this job sheet does not attempt to specify just what type casting the student should procure. If obtainable, however, the pieces should be at least three-eighths of an inch or one-half inch in thickness. This will give the student the opportunity to chip away the sides of the crack, so as to form a ninety degree vee. As stated in the text, these chips should be saved and used later while the welding is progressing.

The selection of the proper type of filler rod and flux to be used is left entirely to the student as by this time with the information given to him in the previous lessons, he should have no difficulty in making a proper selection.

After the weld has been completed, the piece should be placed in a vise and broken directly through the weld. The student should note whether or not the filler rod has fused uniformly with the original casting. He should also note whether or not the added material is filled with blow holes. The presence of blow holes in the weld will make a weak, poor job and should be remedied by using the proper flux and filler rod.

As in previous job sheets this exercise should be repeated until the student is capable of making a weld that is good in all respects.

Questions:

1. What is the purpose of the bead shown in Figure No. 1 running parallel to the weld?
2. What is the usual composition of bell metal?
3. Why should a small hole be drilled just beyond the end of a crack in a bell?
4. What type of welding rod is used for welding bronze?
5. How should a crack in a bronze casting be prepared for welding?
6. How does the bending of spoke "A," Figure 5, serve to compensate for the expansion and contraction of the metal during welding?

Lesson No. 20

Airplane Welding

THE student is now a competent welder, if he has carefully studied this course of instruction and has actually accomplished all of the jobs specified in the job sheets. In the early part of the course he became a skillful welder of sheet steel. Later in the course he welded small diameter pipe and became skillful in making all kinds of joints in the lighter gauges of steel as well as in the thicker sections.

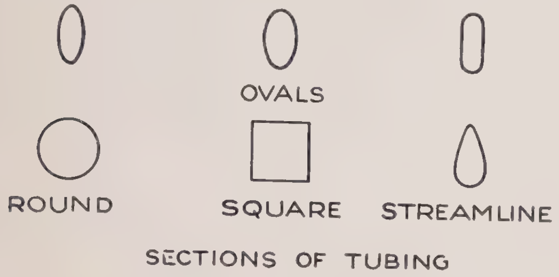


Figure 1—Sketches Illustrating the Various Sections of Tubing Used for Airplane Construction.

Much of this experience now becomes of value in applying the welding process to the joining of steel tubing for the fuselage of the airplane. The student has already had sufficient experience to enable him to make excellent welds in sheet steel; it is, therefore, only necessary to apply this skill to the welding of the special tubing, to gain the required knowledge of the kind of joints used and to learn the methods found most satisfactory for the welding of airplanes.

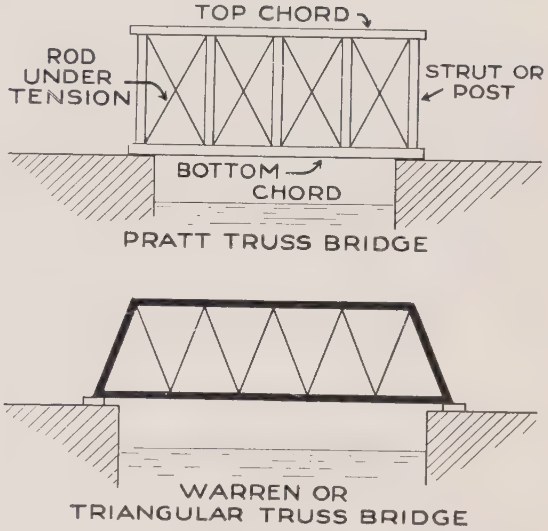


Figure 2—Sketches Illustrating Pratt and Warren Trusses Applied to Bridge Construction. These Trusses were Named after the Bridge Engineers Who First Designed Them and The Principles Have Now Been Applied to the Construction of the Airplane Fuselage. The Pratt Truss is Made up of Heavy Cords at the Top and at the Bottom with Vertical Posts Between These Cords. The Rectangles Thus Formed are Connected at the Corners by Diagonal Tie Rods Under Tension. The Warren Truss, on the Other Hand, Divides the Side Members of the Bridge Directly into Triangles.

The welder, however, must not assume that, because he is skilled in welding sheet metal, he can enter the field of airplane welding without special knowledge and experience and make a suc-

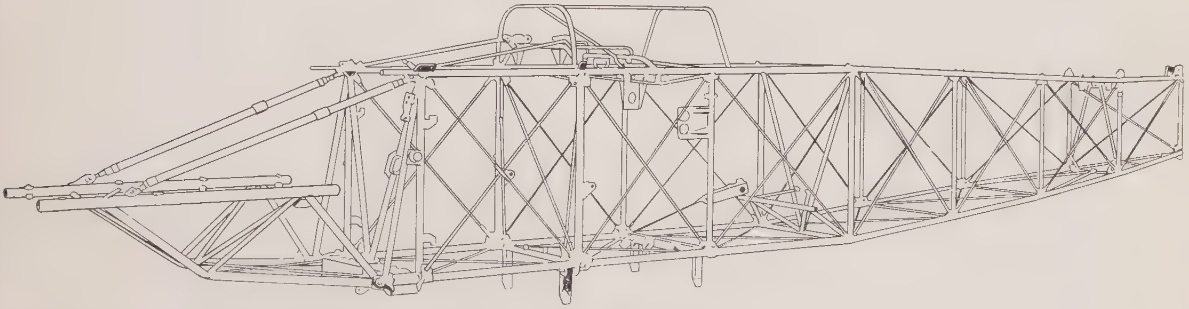


Figure 3—Sketch Showing an Airplane Fuselage, the Design of Which is Based Upon the Principles of the Pratt Truss. The Side of the Fuselage is Divided into Rectangles with Vertical Posts in Compression, and Diagonal Wires in Tension.

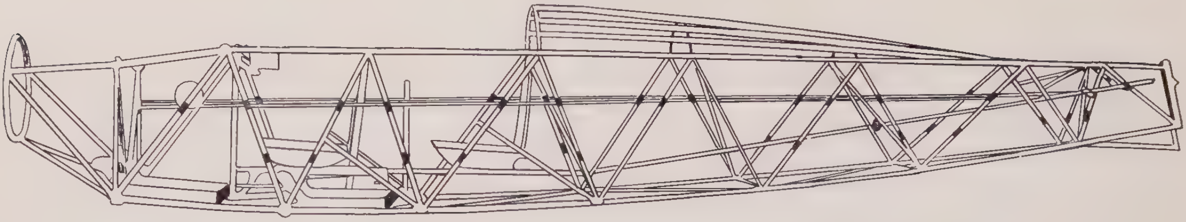


Figure 4—Sketch Showing an Airplane Fuselage, the Design of Which is Based Upon the Principles of the Warren Truss. It will be Noted that this Construction Divides the Side of the Fuselage into Triangles, Made Entirely of Tubing. No Wires are Used.

cess of it. There are many new practices in the welding of airplane tubing which are essential to the successful construction of the fuselage and other parts. There are types of joints which might be entirely satisfactory for other classes of work, which will not serve at all in the construction of airplanes. There are many special forms of joints which give greater strength and avoid weak sections of the fuselage. The Bureau of Standards is now determining the strength of many forms and types of joints in airplane tubing and a report upon this investigation will soon be available. The welder must know what these special practices are and how they affect the strength of his work before he can become really proficient.

The welder, already skilled in other lines of welding, must therefore, enter the airplane field with an open mind and a willingness to learn and profit by the experiences of the engineers and the foremen who have specialized in airplane welding. He can combine the skill, which he has already gained, with the knowledge which he can secure, to make himself a competent welder in this new field.

It seems to be the opinion of many of the engineers and foremen, in airplane manufacturing plants, that it is better to secure men who know absolutely nothing about welding and teach them the process, rather than to hire skilled welders and attempt to convert them into good airplane welders. It is hard to believe that the skill, which a good sheet metal welder possesses, cannot be turned to good account in welding airplane tubing. It is recognized, however, that many men are more skillful in welding heavy work, such as iron and steel castings, heavy steel plates, etc. than in welding sheet metal; these men should stick to the class of work in which they excel and not attempt to enter a field for which they are perhaps unqualified. The sheet metal welder, on the other hand, already has become skilled in light work and should be able to adapt his skill to the airplane field, providing he is willing to accept the new practices and methods already in use.

In this lesson, only the elementary principles and practices in joining airplane tubing are considered. The steel itself, the various types of joints and welding practices which are used to construct the fuselage and other welded parts are studied. It is recognized that present practices are subject to rapid change and that these practices are not universal. Some companies, manufacturing airplanes, prefer one set of practices, while others believe in and utilize entirely different designs and methods. The welder who enters the airplane field will, of course, work in accordance with the requirements and practices of the engineer and foreman of the company by which he is employed. He will not be called upon, nor permitted, to use his own ideas and ingenuity, as he is ordinarily in repair work.

The reason for this is the fact that the airplane is largely a product of the engineer, and its con-

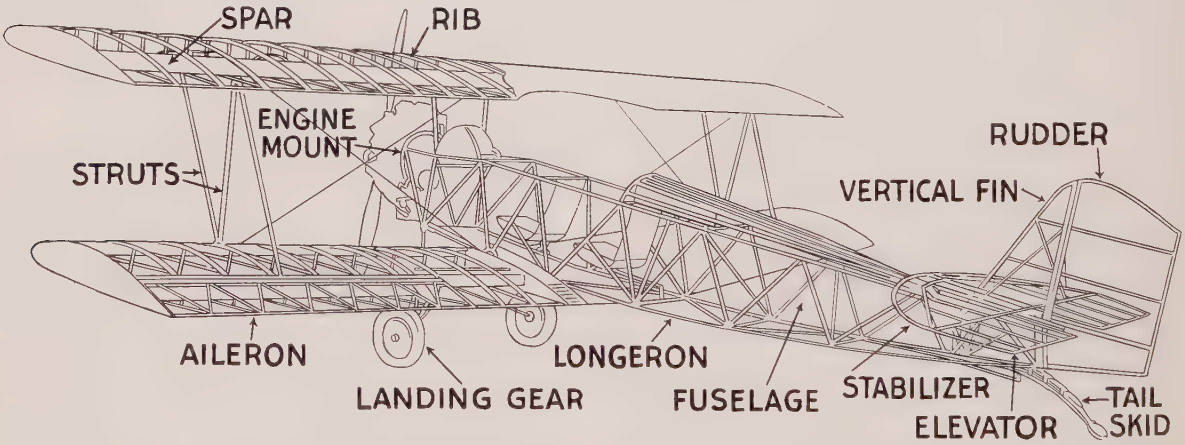


Figure 5—Sketch Showing the Various Parts of an Airplane.

struction is, as it should be, under his rigid control. There are many factors entering into the construction of an airplane about which the average welder cannot possibly be informed. These can only be understood by the engineer and the metallurgist, and all welding must of necessity be accomplished under their close supervision and control. The welder must do the work as he is instructed to do it. The most important thing which he should bear in mind is the necessity for producing the best welds of which he is capable, because upon the strength of his work will depend the lives of others.

What Is the Fuselage?

The fuselage of the modern airplane is the main framework or body of the plane, supporting most of the weight, including the engine, pilot, passengers and cargo, to which the wing surfaces are attached. The fuselage extends from the engine mount, at the forward end of the plane, to the tail and must be constructed so that the greatest strength is secured with the least weight. The fuselage, which is most commonly used in the United States today, is made of steel tubing, the joints of which are welded together with the oxy-acetylene torch. The sides of the fuselage, which are generally rectangular in shape, are trusses built up of steel tubing and following in design the principles of bridge trusses. Fuselage construction is sometimes designated by the form of the truss members named after the bridge engineers who originally designed the truss for bridge purposes. It is not necessary to specifically study truss construction, because it is a division of engineering and not of welding, but the illustrations will give an idea of the subject.

Chrome-Molybdenum Steel

Many tubular fuselages have been built of medium carbon seamless drawn tubing with the joints welded. While this tubing was strong and made a good fuselage, engineers have more recently developed a special steel from which tubing is made having far greater strength and being

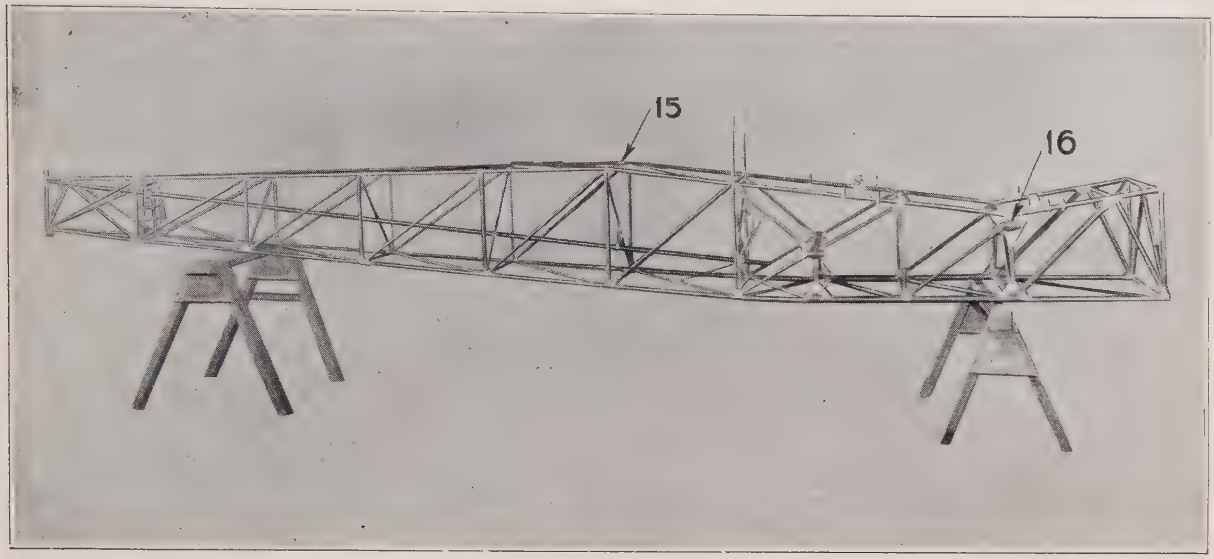


Figure 6—Photograph of a Welded Fuselage. The Wing Hinge, Marked 16 in This Photograph is Shown in Detail in Figure 16. A Close Up View of the Joint Marked 15, Between the Longeron and the Vertical and Diagonal Tubes is Shown in Figure 15.

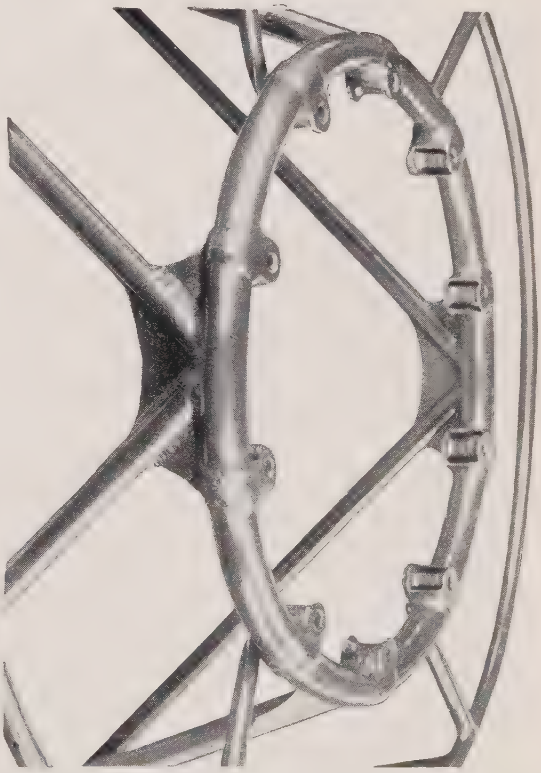


Figure 7—Photograph Showing the Forward End of the Engine Mount of a Welded Fuselage. This Photograph Gives an Excellent Idea of the Joints and Gusset Plates Connecting the Circular Part of the Mount to the Supporting Tubing. The Special Fittings for the Attachment of the Engine Are Also Shown.

more easily welded than the medium carbon tubes previously used. This steel is an alloy containing chromium and molybdenum. The addition of these metals to steel in the quantities specified produces a tubing which will harden in air from a wide range of temperatures without greatly altering the mechanical properties of the metal. The steel has a tensile strength, without special heat treatment, of 95,000 pounds per square inch and can be heat treated easily and dependably to 180,000 pounds per square inch. The addition of chromium makes steel harder and molybdenum seems to make the steel even more weldable. In combination, these metals added to steel make it very strong and able to withstand repeated shocks.

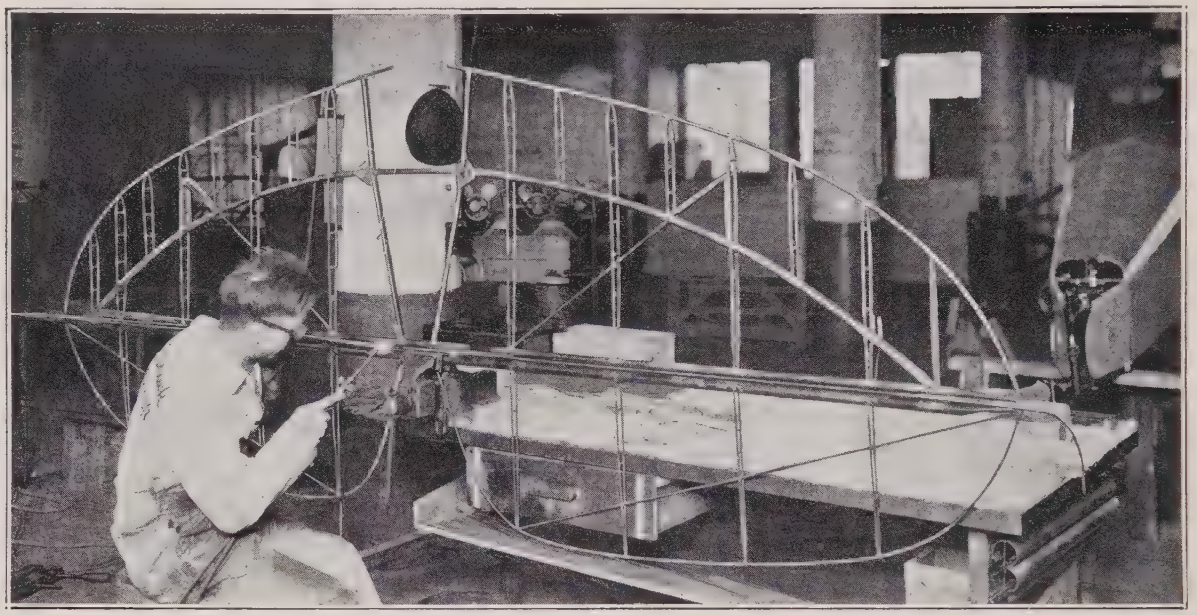


Figure 8—Photograph of a Welded Steel Stabilizer Frame. The Two Elevators are also Shown Hinged to the Stabilizer. There are over Five Hundred Welds in This Assembly.

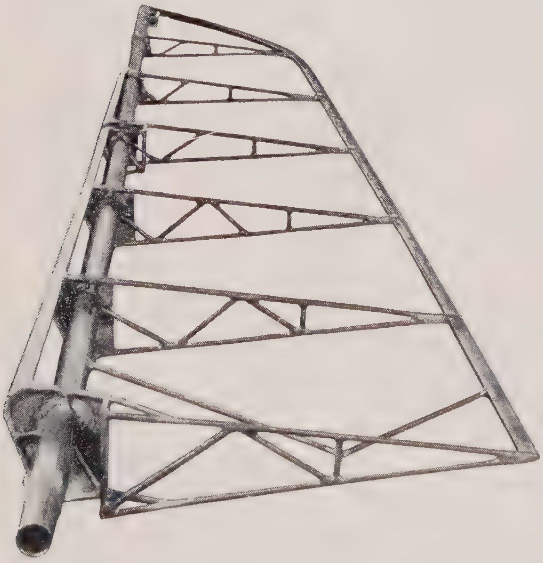


Figure 9—Photograph Showing a Right Aileron, Made Entirely of Steel Tubing and Plates With Every Joint Welded.

Chemical Analysis of National-Shelby Steel Airplane Tubing

Carbon Steel

Carbon	0.20-0.30	per cent
Manganese	0.50-0.80	per cent
Phosphorus	0.045	maximum
Sulphur	0.05	maximum

Tensile strength, minimum, 55,000 lbs. per sq. in.

Chrome-Molybdenum Steel

Carbon	0.25-0.35	per cent
Manganese	0.40-0.60	per cent
Phosphorus	0.040	maximum
Sulphur	0.045	maximum
Chromium	0.80-1.10	per cent
Molybdenum	0.15-0.25	minimum

Tensile strength, minimum, 95,000 lbs. per sq. in.

The strength of chrome-molybdenum steel seems to be least affected by welding. Heat treatment is accomplished by heating the metal to approximately 1650 degrees Fahrenheit and quenching it. The temper is afterwards drawn to the required hardness.

Chrome-molybdenum steel tubing is now used, in connection with welding, for a very large number of the fuselages for airplanes manufactured in the United States. This tubing is seamless drawn tubing made in round, streamline and square sections. The round sections are ordinarily used for the construction of the fuselage, empennage, ailerons, etc. The streamline sections are used for exposed tubing, like the struts of the wings and parts of the undercarriage of the plane, which come in contact with the air. The object of the streamline section is to prevent eddies of the air as much as possible. The square tubing is used by some manufacturers around the cockpit, because this section is thought to be more resistant to crushing and hence offers the pilot more protection.

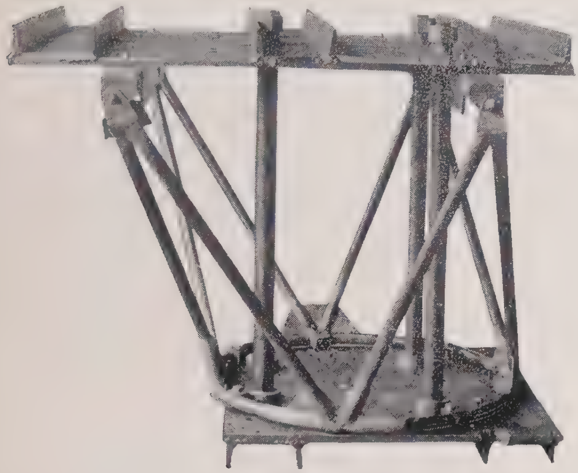


Figure 10—This Photograph Illustrates a Type of Jig Used for Welding the Engine Mounts. The Jig Is Made of Two Large Plates Reinforced by Channel Iron, Welded at the Top and the Bottom, to Prevent Warping. The Two Plates Are Held Together in Alignment by Four Substantial Posts. With Such a Jig and Careful Workmanship, the Engine Mounts for a Certain Model Plane Will Be Interchangeable.

The size of the tubing ordinarily used in airplane construction is given in Table 1. For a large part of the fuselage, similar to that shown in Figure 6, the thickness of the wall of the tubing is 0.035 inches, which is slightly more than one-thirty-second of an inch. Steel tubing and welding are also used almost exclusively in constructing the framework of ailerons, stabilizers, elevators, rudders, parts of the landing gear, etc.

Definitions of Parts of An Airplane

There are some words used in this lesson with which the student may not be familiar and these words, or names, are, therefore, defined:

Aileron: An aileron is a pivoted, or hinged, section or surface, usually attached to the rear edge of the wing.

Cowling: The cowling is a removable cover, usually placed over the engine and sometimes over other parts of the fuselage.

Elevator: A movable, auxiliary, horizontal surface, usually hinged to the stabilizer, to control the upward or downward movement of the plane.

Empennage: The tail assembly including the stabilizers, elevators, rudder and fin.

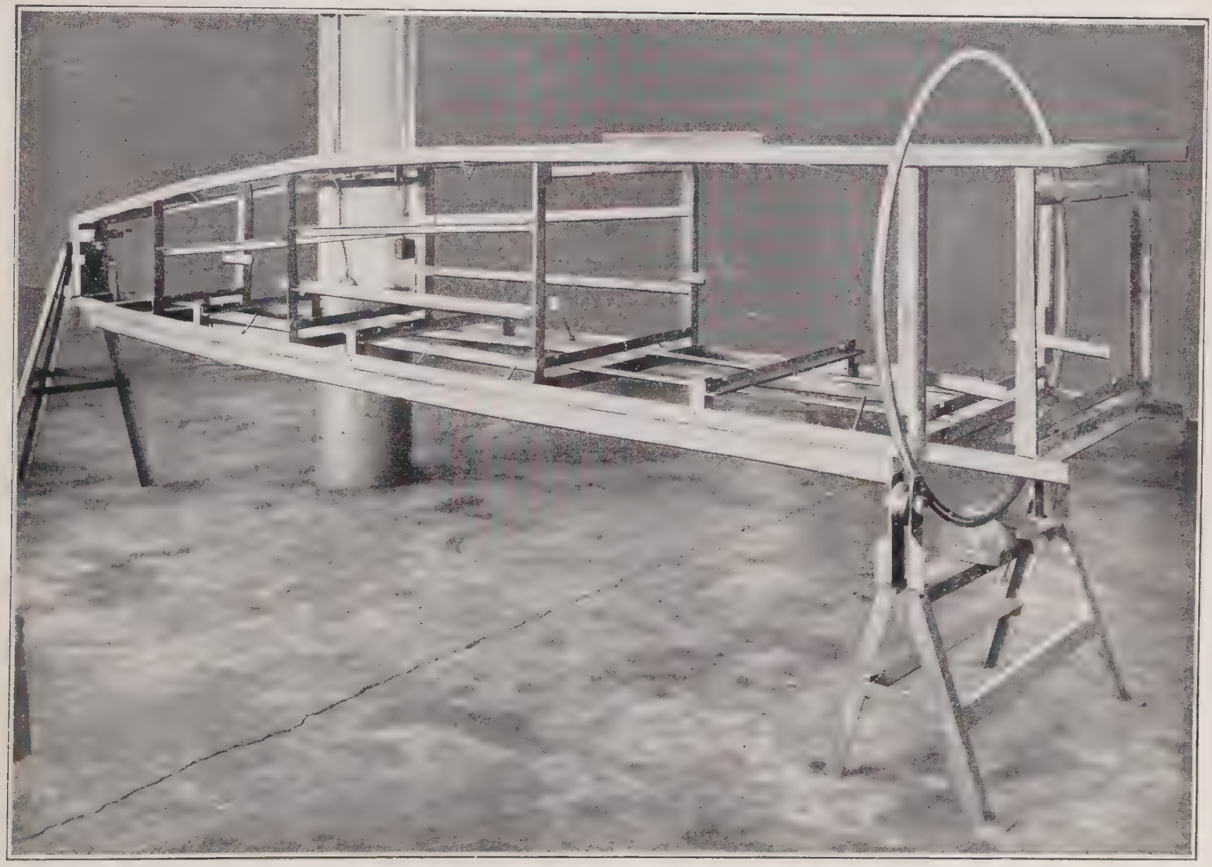


Figure 11—Photograph of a Jig for Welding the Fuselage of a Small Plane. This Type of Jig can be Turned About Its Axis and is Convenient for the Welder on this Account. Usually only Two Men can Work at a Time on a Jig of this Type.

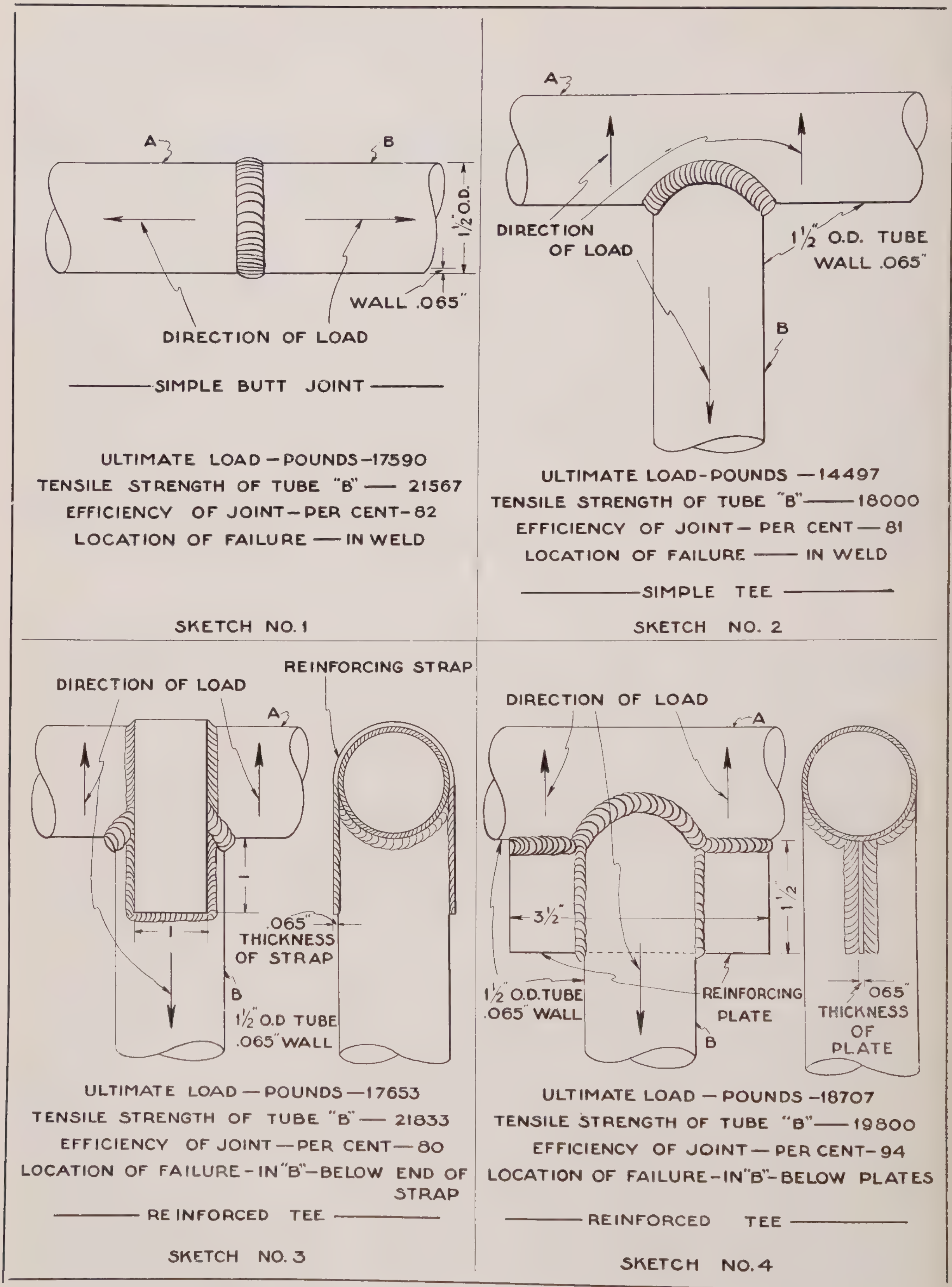
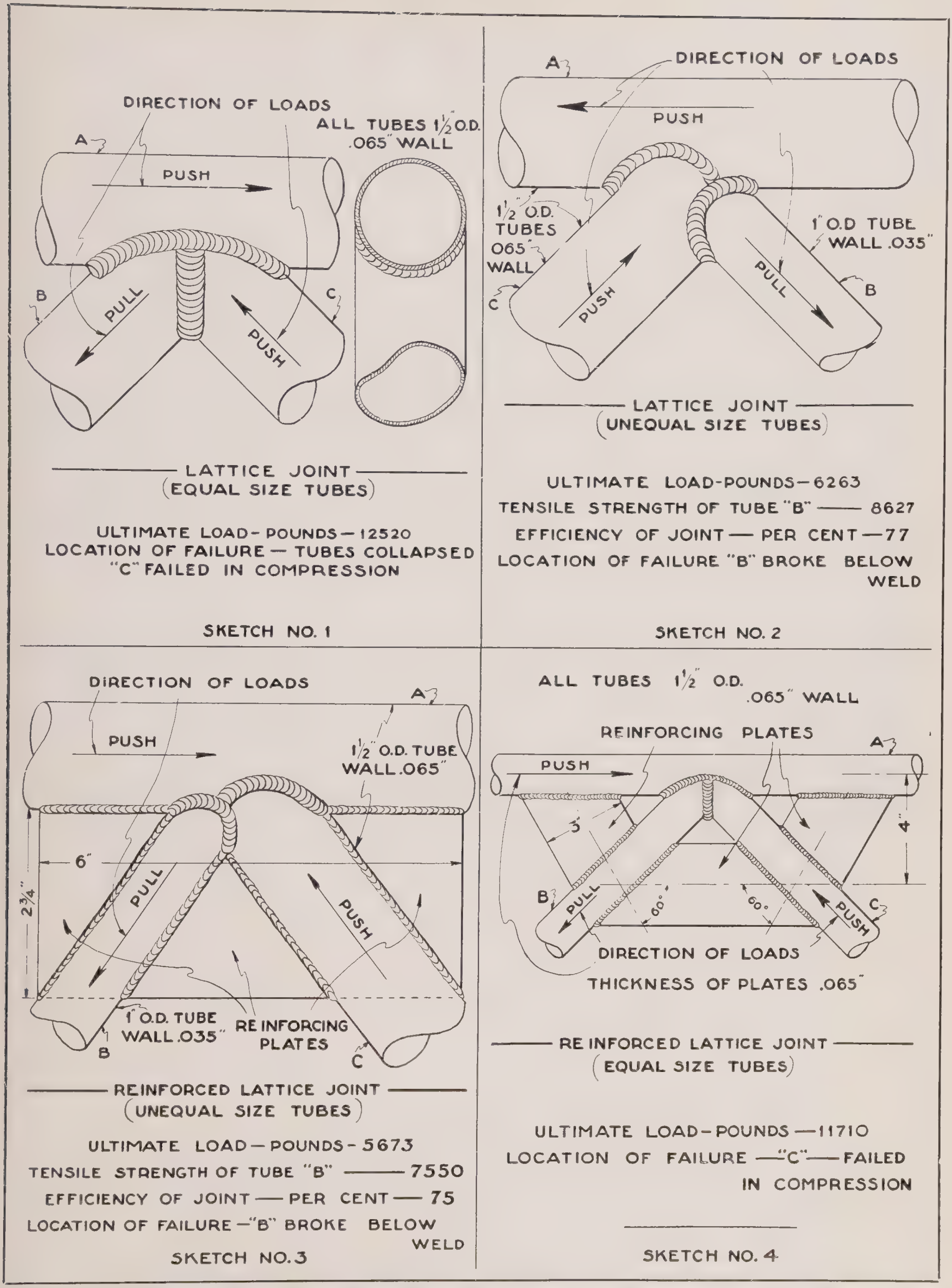

A
B
1½" O.D.
WALL .065"
DIRECTION OF LOAD
SIMPLE BUTT JOINT
ULTIMATE LOAD—POUNDS—17590
TENSILE STRENGTH OF TUBE "B"—21567
EFFICIENCY OF JOINT—PER CENT—82
LOCATION OF FAILURE—IN WELD
SKETCH NO. 1
A
DIRECTION OF LOAD
1½" O.D. TUBE
WALL .065"
B
ULTIMATE LOAD-POUNDS—14497
TENSILE STRENGTH OF TUBE "B"—18000
EFFICIENCY OF JOINT—PER CENT—81
LOCATION OF FAILURE—IN WELD
SIMPLE TEE
SKETCH NO. 2
DIRECTION OF LOAD
REINFORCING STRAP
A
1
1
.065" THICKNESS OF STRAP
B
1½" O.D TUBE
.065" WALL
ULTIMATE LOAD—POUNDS—17653
TENSILE STRENGTH OF TUBE "B"—21833
EFFICIENCY OF JOINT—PER CENT—80
LOCATION OF FAILURE-IN "B"-BELOW END OF STRAP
REINFORCED TEE
SKETCH NO. 3
DIRECTION OF LOAD
A
3½"
1½"
1½" O.D.TUBE
.065" WALL
REINFORCING PLATE
B
.065" THICKNESS OF PLATE
ULTIMATE LOAD—POUNDS—18707
TENSILE STRENGTH OF TUBE "B"—19800
EFFICIENCY OF JOINT—PER CENT—94
LOCATION OF FAILURE-IN "B"-BELOW PLATES
REINFORCED TEE
SKETCH NO. 4

Figure 12—These Sketches Show the Results of Tests Upon Simple Butt and Tee Joints in Airplane Tubing Made With and Without Reinforcing Plates. The Tests Were Made by the Bureau of Standards.


DIRECTION OF LOADS
ALL TUBES 1½" O.D. .065" WALL
A
PUSH
B
PULL
C
PUSH
DIRECTION OF LOADS
A
PUSH
1½" O.D. TUBES .065" WALL
C
PUSH
1" O.D TUBE WALL .035"
PULL
B
DIRECTION OF LOADS
A
PUSH
1½" O.D. TUBE WALL .065"
6"
2¾"
PULL
PUSH
1" O.D. TUBE WALL .035"
B
REINFORCING PLATES
C
ALL TUBES 1½" O.D. .065" WALL
REINFORCING PLATES
A
PUSH
3"
4"
B
PULL
60°
60°
PUSH
C
DIRECTION OF LOADS
THICKNESS OF PLATES .065"

LATTICE JOINT
(EQUAL SIZE TUBES)

ULTIMATE LOAD-POUNDS—12520
LOCATION OF FAILURE—TUBES COLLAPSED
"C" FAILED IN COMPRESSION

SKETCH NO. 1

LATTICE JOINT
(UNEQUAL SIZE TUBES)

ULTIMATE LOAD-POUNDS—6263
TENSILE STRENGTH OF TUBE "B"—8627
EFFICIENCY OF JOINT—PER CENT—77
LOCATION OF FAILURE "B" BROKE BELOW WELD

SKETCH NO. 2

REINFORCED LATTICE JOINT
(UNEQUAL SIZE TUBES)

ULTIMATE LOAD—POUNDS-5673
TENSILE STRENGTH OF TUBE "B"—7550
EFFICIENCY OF JOINT—PER CENT—75
LOCATION OF FAILURE—"B" BROKE BELOW WELD

SKETCH NO. 3

REINFORCED LATTICE JOINT
(EQUAL SIZE TUBES)

ULTIMATE LOAD-POUNDS—11710
LOCATION OF FAILURE—"C"—FAILED IN COMPRESSION

SKETCH NO. 4

Figure 13—These Sketches Show Lattice Joints, Which Were Tested by the Bureau of Standards to Determine the Efficiency of the Joints as Compared With the Strength of the Diagonal Tubing. Welding Reinforcing Plates to These Joints Increased the Strength of the Joint Itself, But Did Not Influence the Strength of the Diagonal Tubing.

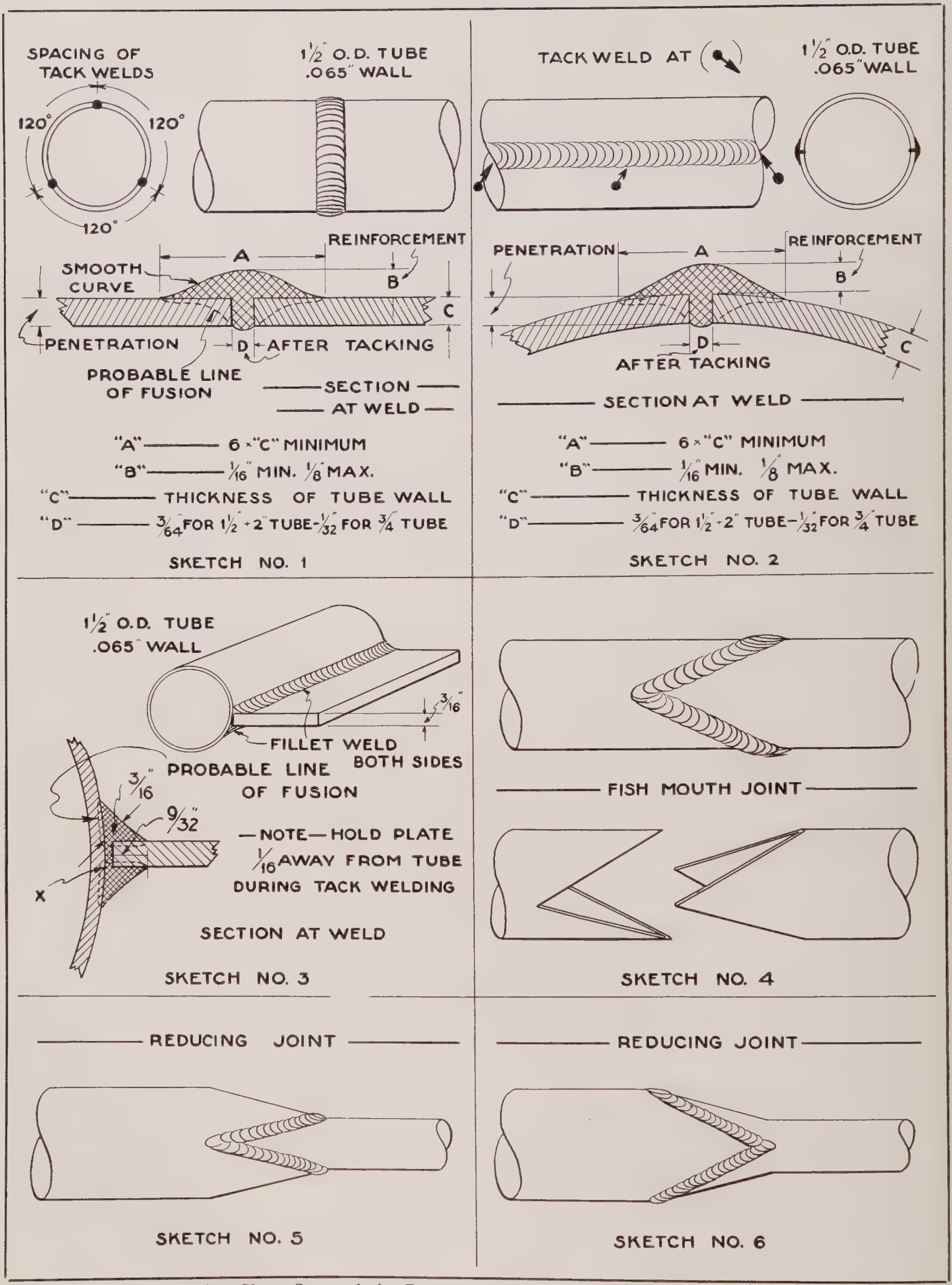

SPACING OF TACK WELDS
120°
120°
120°
1½" O.D. TUBE
.065" WALL
SMOOTH CURVE
A
REINFORCEMENT
B
C
PENETRATION
D
AFTER TACKING
PROBABLE LINE OF FUSION
SECTION AT WELD
"A" — 6 × "C" MINIMUM
"B" — 1/16" MIN. 1/8" MAX.
"C" — THICKNESS OF TUBE WALL
"D" — 3/64" FOR 1½"-2" TUBE-1/32" FOR ¾" TUBE
SKETCH NO. 1
TACK WELD AT
1½" O.D. TUBE
.065" WALL
PENETRATION
A
REINFORCEMENT
B
D
C
AFTER TACKING
SECTION AT WELD
"A" — 6 × "C" MINIMUM
"B" — 1/16" MIN. 1/8" MAX.
"C" — THICKNESS OF TUBE WALL
"D" — 3/64" FOR 1½"-2" TUBE-1/32" FOR ¾" TUBE
SKETCH NO. 2
1½" O.D. TUBE
.065" WALL
3/16"
FILLET WELD BOTH SIDES
PROBABLE LINE OF FUSION
3/16"
9/32"
X
—NOTE— HOLD PLATE 1/16" AWAY FROM TUBE DURING TACK WELDING
SECTION AT WELD
SKETCH NO. 3
FISH MOUTH JOINT
SKETCH NO. 4
REDUCING JOINT
SKETCH NO. 5
REDUCING JOINT
SKETCH NO. 6

Figure 14—These Sketches Show Some of the Recommendations of the Committee on Welding Procedure of the American Bureau of Welding. Sketches 4, 5 and 6 Illustrate Fish-Mouth Joints in Tubes of Equal and Unequal Diameters.

Fuselage: The fuselage is the main framework of the body of an airplane. It supports the engine; the main gasolene and oil tanks; the pilot, passengers and cargo of the plane. The wings, the tail units, the engine mount and the landing gear are attached to the fuselage.

Landing Gear: The landing gear of an airplane is the under structure, which supports the plane while on the ground. It may be of the wheel-type, skid type, ski type, boat or float type, or a combination of both land and water types.

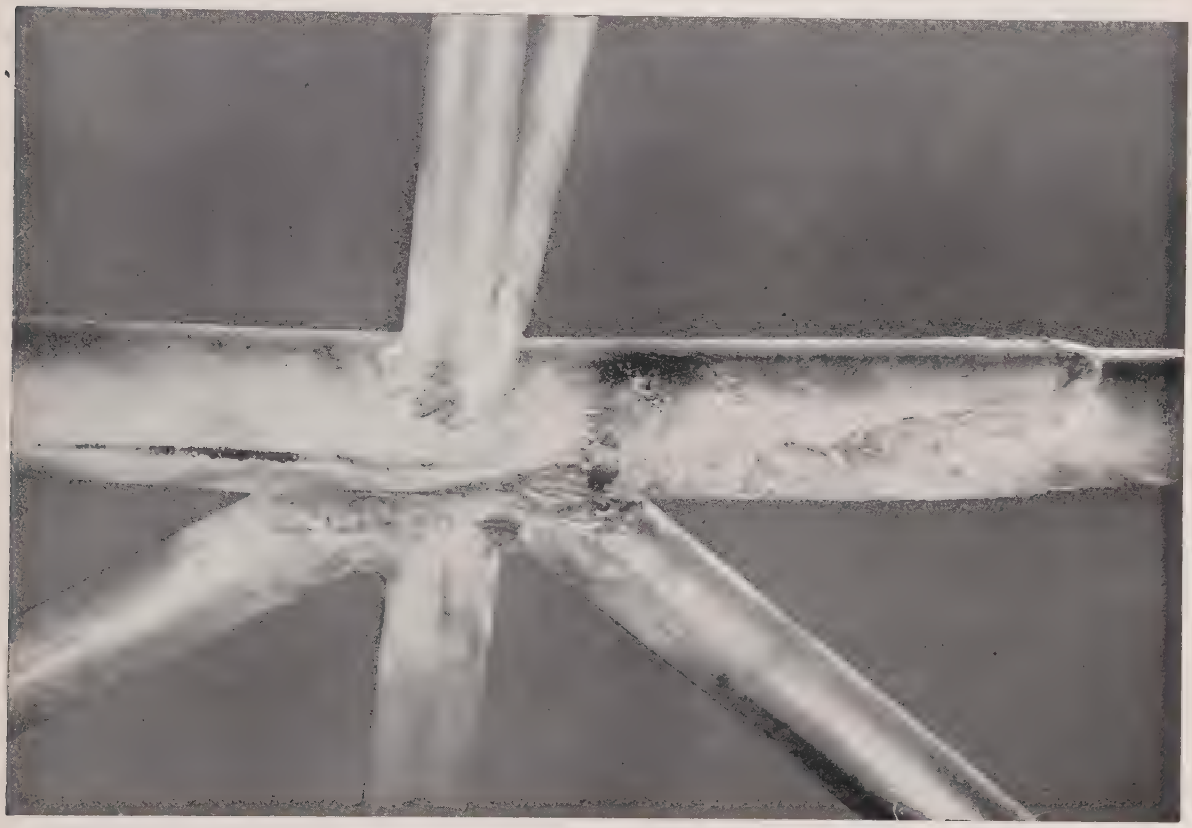


Figure 15—Close Up View of a Joint Between the Top Longeron and the Lateral and Vertical Bracing of the Fuselage. This Joint is Marked 15 in the Photograph of the Fuselage, Figure 6.

Longeron: A longeron is a main supporting member of the fuselage usually running fore-and-aft of the framework. It is usually a continuous member supporting several units of the framework.

Rudder: The rudder is a movable, vertical surface, usually located at the rear of the plane. It is controlled from the cockpit and is used to change the direction of the plane. It is equivalent to the rudder of a boat.

Stabilizer: A stationary surface, usually located at the rear of an airplane, in a horizontal position, used to prevent a pitching motion of the plane.

Welding Rods

In most welding of chrome molybdenum steel tubing, low carbon welding rods are used. Experimental work has been done and tests have been made of welds where alloy steel and chrome-molybdenum welding rods were used, but these experiments have not yet shown sufficient advantage in the use of alloy rods to offset the greater difficulty in welding with them. At present, the most satisfactory welding rods, from a welding standpoint, are the low carbon rods. Alloy rods, as shown on page 153, produce welds having greater strength, but they do not flow as easily and require more than ordinary skill in the making of welds. It has been found in the welding of chrome-molybdenum airplane tubing that the use of alloy rods does not always produce uniform results; some of the welds may have a very high tensile strength, while others may be disappointingly low. The best all around results so far appear to have been produced with low carbon welding rods of the American Welding Society specifications G-No. 1A, when welding chrome-molybdenum steel tubing.

Flame Characteristics and Torch Manipulation

For welding airplane tubing, the character of the flame should be neutral in all cases. This is in accord with the general practice established for the welding of steel in the first ten lessons of the course. The motion of the torch and the method of welding may be the semi-circular movement method, illustrated in Figures 1, 2 and 3, page No. 26, or it may be the advanced flame method from left to right, illustrated in Figure 12, on page No. 82. Part of the weld may be made by one method and part by the other, depending entirely upon the judgment of the welder.

The Use of Jigs for Assembling Tubing

Good jigs are essential in assembling the fuselage, stabilizers, rudders, ailerons and other parts made of tubing. The tubes are cut to correct length, using templets, with high speed circular saws. The jigs are made of plates, angles, channels and other structural sections, built up to the required dimensions and equipped with quick opening clamps and sockets to hold the tubes, so that they are accurately assembled during welding. Some of these jigs are very large and are so arranged so that the welder can climb underneath, on each side and on top of the framework, while he is welding.

Types of Joints

In a paper presented before the Philadelphia section of the American Welding Society in October, 1928, Professor H. L. Whittemore, Chief Engineer of the Mechanical Section of the United States Bureau of Standards, made a preliminary report upon the strength of welded airplane tubing. This report gave some very valuable information with reference to the strength of various types of joints made by welding carbon steel, airplane tubing. No test of welded chrome-molybdenum tubing was reported upon, but the investigation has been continued and a final report No. 348 has been published by the National Advisory Committee for Aeronautics. The subject is, of course, a very broad one and this final report will provide both the engineer and the welder more detailed information with reference to the strength of joints than has been available heretofore. The tests covered by this report were of welded joints in chrome-molybdenum steel tubing.

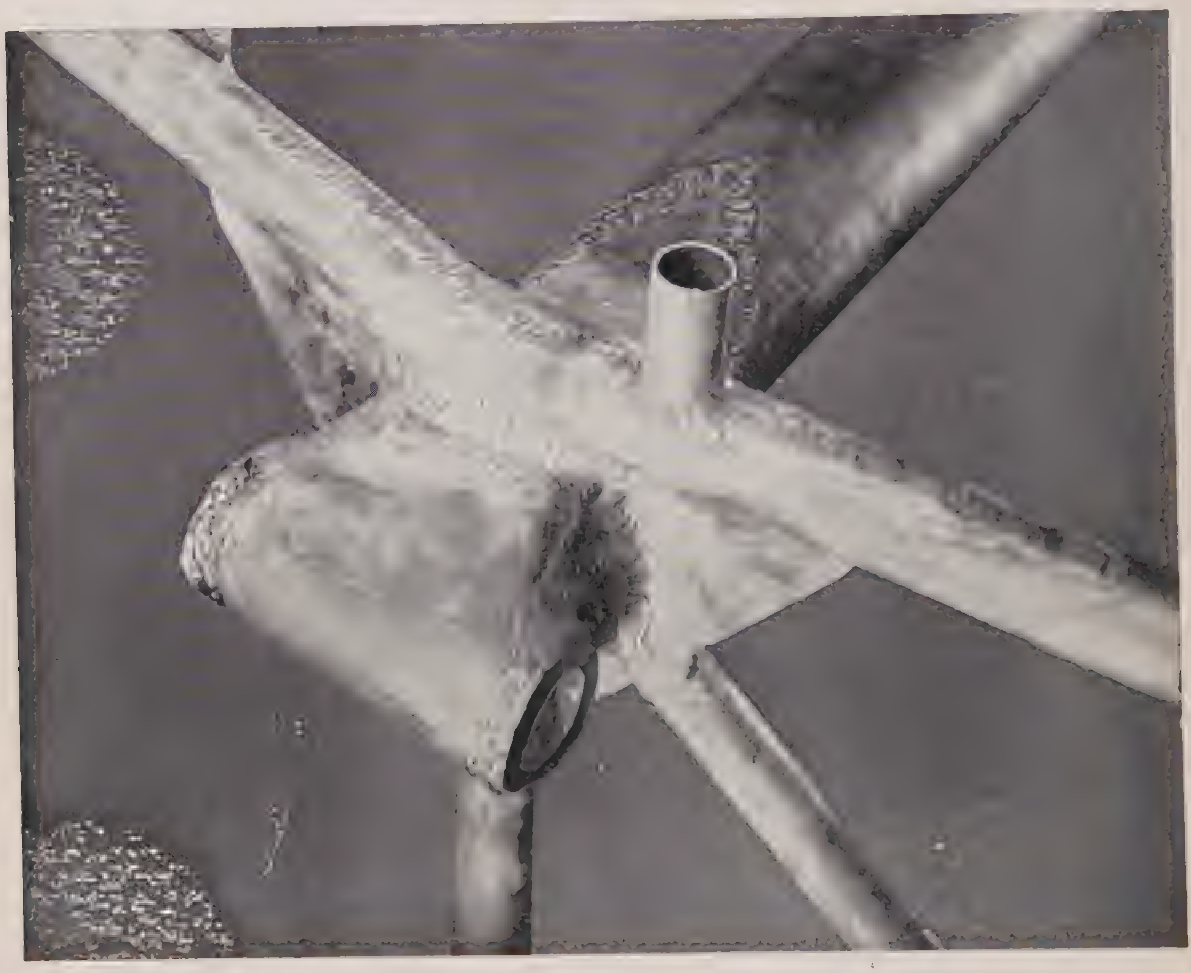


Figure 16—Close Up View of the Wing Hinge Joint of the Fuselage Marked 16 in Figure 6.

At the same meeting of the American Welding Society, Mr. H. H. Moss, of the Committee on Welding Procedure, presented a general procedure control for airplane welding which sets forth approved welding practice for making joints in airplane tubing.

In Figure 12, sketches Nos. 1, 2, 3 and 4, illustrate respectively a simple butt joint welded between pieces of steel airplane tubing; a simple tee joint; a tee joint reinforced with a strap and a tee joint reinforced with plates. These joints were all welded, the tubing being carbon steel, and tested by the Bureau of Standards, with the results shown. The figures given are the average of three tests for each joint. It will be noted that the efficiency of the simple butt joint is eighty-two per cent; of the simple tee joint eighty-one per cent; and of the reinforced tee joints, the reinforcement being a strap, eighty per cent. The tee joints reinforced with plates, shown in Sketch No. 4 on the other hand, gives an efficiency of ninety-four per cent. A little study of these figures and sketches will show the differences in the design of these joints and their relative strength.

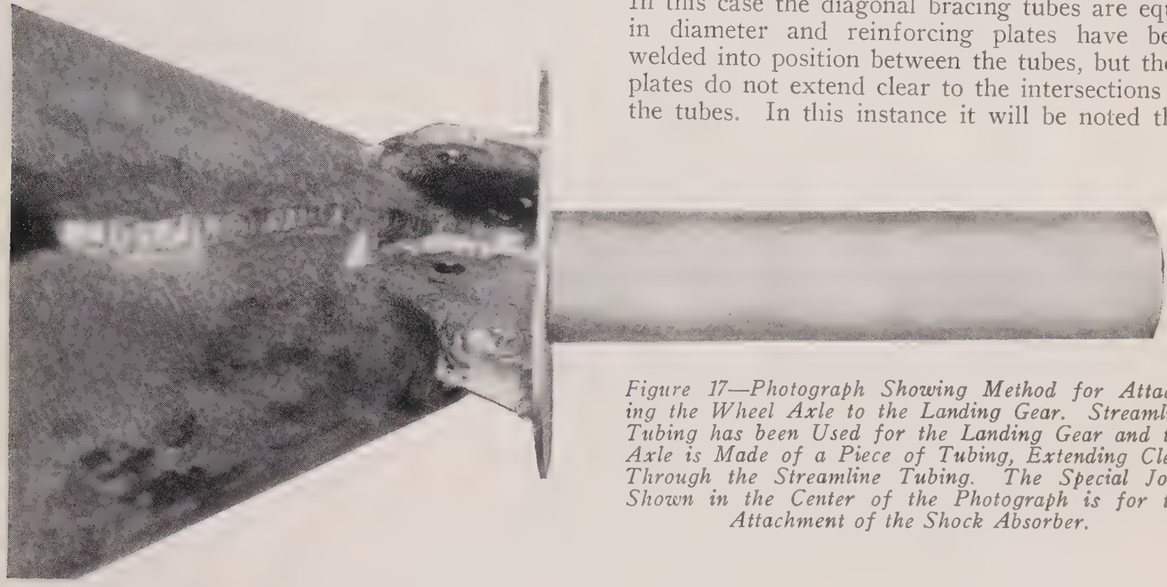


Figure 17—Photograph Showing Method for Attaching the Wheel Axle to the Landing Gear. Streamline Tubing has been Used for the Landing Gear and the Axle is Made of a Piece of Tubing, Extending Clear Through the Streamline Tubing. The Special Joint Shown in the Center of the Photograph is for the Attachment of the Shock Absorber.

In Figure 13 various lattice joints are shown, as they would be made between the longerons and the lateral bracing tubes of a fuselage. In Sketch No. 1, Figure 13, a joint of this kind is shown made without any plate reinforcing. The tubes B and C are of equal diameters and the arrows indicate the direction of the loads. The welded joints are made by cutting the tubing to the correct miter and shaping the ends of the tubes so that they will fit together, as indicated in the sketch. The joint is then welded. Sketch No. 1, Figure No. 13, shows an ultimate load on this joint of 12,520 pounds when the tube C collapsed in compression.

In Sketch No. 2, Figure No. 13, the diagonal brace B was smaller in diameter than the diagonal brace C. In this instance the tube B broke below the weld, indicating an efficiency of approximately seventy-seven per cent. The failure, however, was in the tube and not in the joint. In Sketch No. 3, Figure 13, one of the diagonal braces is smaller in diameter than the other, but the joint is reinforced by welding three reinforcing plates in position between the diagonal tubes and the longeron. In this instance it will be noted that the tube B broke below the weld and that the efficiency of the joint was approximately seventy-five per cent. In other words, the reinforcing plates, used in making this joint, did not materially strengthen the structure, because the weak link was the tube B.

Another instance of a reinforced joint of this kind is shown in Sketch No. 4, Figure No. 13. In this case the diagonal bracing tubes are equal in diameter and reinforcing plates have been welded into position between the tubes, but these plates do not extend clear to the intersections of the tubes. In this instance it will be noted that the tube C failed in compression. The reinforcing plates, therefore, did not in reality reinforce this structure, because the tube C was the weakest member, and the simple joint without the reinforcing plates was strong enough for the purpose; that is, stronger than the weakest member. Both Figures 12 and 13 indicate the value of testing joints of this kind to show whether or not the joint is not in reality stronger than other members of the structure.

In Sketches Nos. 4, 5 and 6 of Figure 14 types of joints called fish-mouth joints are shown. In Sketch No. 4 the fish-mouth joint is between two pieces of tubing of equal diameter. In Sketches 5 and 6, the joints are between pieces of tubing of unequal diameters. These latter joints are known as reducing joints. The object of the fish-mouth joint, as compared with the simple butt joint, is to increase the length of the weld and to place the weld in a position so that it will be under shearing stress instead of direct tensile stress when opposite loads are applied to pull the joint apart. By increasing the length of the weld in this manner, and subjecting it to shearing stresses, the strength of the joint is considerably increased and for this reason fish-mouth joints are used to a far greater extent in the welding of airplane tubing than the simple butt joint. The reducing joints are based upon the same principle and make a strong joint between pieces of tubing of unequal diameters.

Welding Procedure

The committee on welding procedure of the American Bureau of Welding, after careful consideration of the requirements of a welded joint in airplane tubing, have outlined a general procedure control, the complete text of which can be found in the December, 1928, Journal of the American Welding Society.

Some of the recommendations of this procedure control are illustrated in Sketches Nos. 1, 2 and 3, Figure 14. Study of these sketches will show what the welder is expected to do in making a weld in airplane tubing. Sketch No. 1 illustrates a simple butt joint, between two pieces of tubing. It should be understood that the simple butt joint is not a preferred type of joint, as has already been stated in the remarks made, pertaining to fish-mouth joints. The welding procedure, however, would be the same, whether the joint were a fish-mouth joint, or were cut in any other manner. This joint is first tack welded at three points as shown. These points lie equidistant in the circumference.

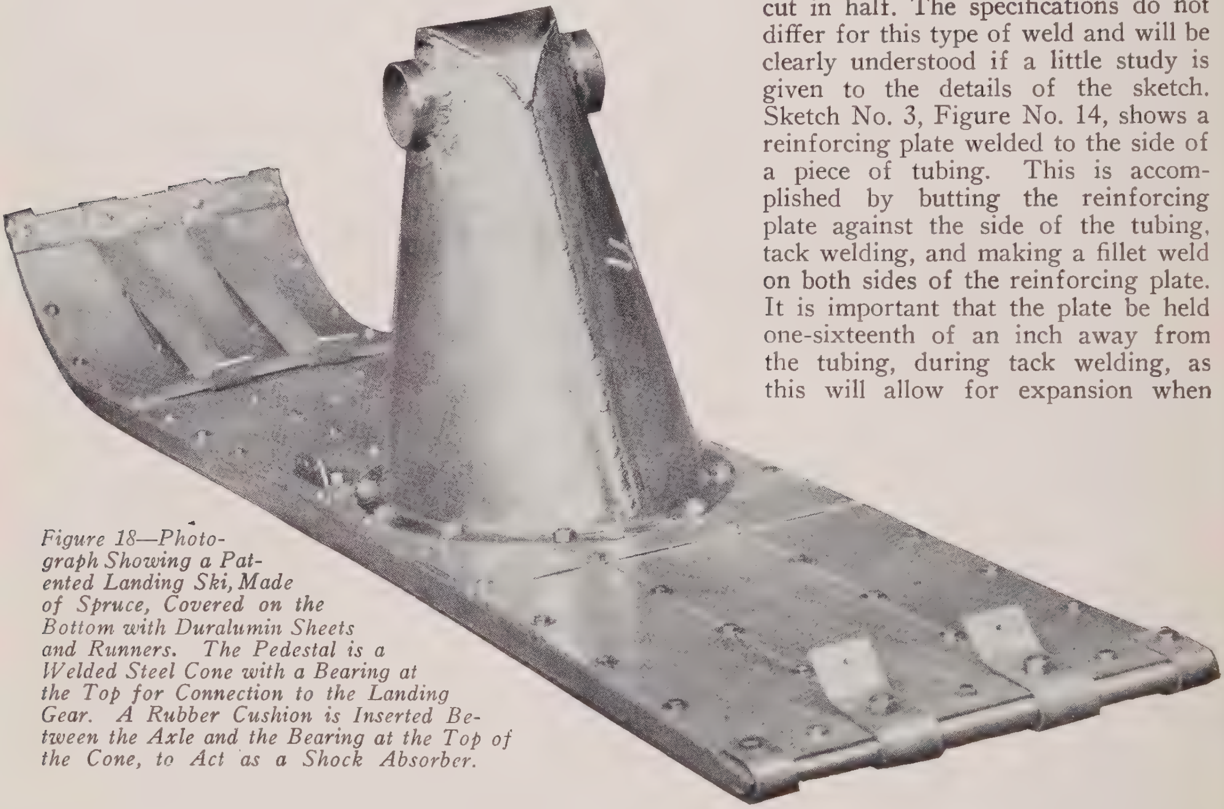


Figure 18—Photograph Showing a Patented Landing Ski, Made of Spruce, Covered on the Bottom with Duralumin Sheets and Runners. The Pedestal is a Welded Steel Cone with a Bearing at the Top for Connection to the Landing Gear. A Rubber Cushion is Inserted Between the Axle and the Bearing at the Top of the Cone, to Act as a Shock Absorber.

A space, D, is left between the tubes, so that after tack welding, this space will be three-sixty-fourths of an inch for tubing from one and one-half inches to two inches and one-thirty-second of an inch for tubing three-quarters inch in diameter. This space permits penetration of the weld clear through to the inside of the tubing. It is absolutely essential in making a weld that it does penetrate in this manner and that the corners of the edges of the tube are fused down to the line, marked, "Probable line of fusion," in Sketch No. 1, Figure No. 14. The height of the reinforcement of the weld is shown at B and should be from one-sixteenth of an inch as a minimum to one-eighth of an inch as a maximum. The width of the reinforcement of the weld, shown as A, should be six times the thickness of the wall of the tube.

In similar manner Sketch No. 2 of Figure No. 14 shows graphically a longitudinal weld between a piece of tubing which has been cut in half. The specifications do not differ for this type of weld and will be clearly understood if a little study is given to the details of the sketch. Sketch No. 3, Figure No. 14, shows a reinforcing plate welded to the side of a piece of tubing. This is accomplished by butting the reinforcing plate against the side of the tubing, tack welding, and making a fillet weld on both sides of the reinforcing plate. It is important that the plate be held one-sixteenth of an inch away from the tubing, during tack welding, as this will allow for expansion when the filet welds are made. The tack welds should be from three-sixteenths to one-quarter inch in length on both sides of the reinforcing plates at each end, that is, there will be four tack welds. The fillet welds are shown in section in the small drawing of Sketch No. 3 and should be nine-thirty-seconds of an inch along the reinforcing plate and an equal amount along the side of the tubing. The thickness of the fillet at the thickest part should be three-sixteenths of an inch. It should be noted that fusion is extended into the reinforcing plate and also into the wall of the tubing, to a dotted line marked, "Probable line of fusion." Penetration in this manner is essential to the strength of the weld and the welder should be particularly careful that he actually fuses the surfaces of the parts being welded. These sketches will indicate to the welder what is expected of him, in actual performance, in making a weld. The same principles and methods can be applied to almost any type of weld, or any form of joint.

It would be possible to continue these sketches of types of joints and methods of making and reinforcing them almost indefinitely, because there are hundreds of different designs for making joints in airplane tubing, which could be devised. Some of these joints would be strong, while others would not be strong enough. Some of the reinforced joints would develop considerably more strength than necessary. Report No. 348 of the National Advisory Committee for Aeronautics gives reliable values for various types of joints and these will be determined by the engineers in charge and the airplane welder will of necessity follow their instructions. This preliminary study will, however, enable him to understand some of the problems involved.

Table No. 1

Thickness of Wall in Fractions of Inch	Thickness of Wall in Decimals of Inch	Sizes in Inches in Which Round Tubing is Available (Outside Diameters)																								
	.028	1/4	5/16	3/8	7/16	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	.035	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	...	...	...	...	...	...	...	...	...	...	...	...
....	.049	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	2 3/8	2 1/2	...	...	...	...
....	.065	1/4	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4	...	...
....	.083	...	5/16	3/8	7/16	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4	2 7/8	3
....	.095	...	...	3/8	7/16	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4	2 7/8	3
....	.109	...	...	...	7/16	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4	2 7/8	3
....	.120	...	...	...	7/16	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4	2 7/8	3
....	.134	...	...	...	...	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4	2 7/8	3
5/32	.156	...	...	...	...	...	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4	2 7/8	3
3/16	.188	...	...	...	...	...	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4	2 7/8	3
7/32	.219	...	...	...	...	...	...	...	7/8	1	1 1/8	1 1/4	1 1/2	1 3/8	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4	2 7/8	3
1/4	.250	...	...	...	...	...	...	...	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4	2 7/8	3
9/32	.281	...	...	...	...	...	...	...	...	...	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4	2 7/8	3
5/16	.313	...	...	...	...	...	...	...	...	...	1 1/8	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4	2 7/8	3
3/8	.375	...	...	...	...	...	...	...	...	...	...	1 1/4	1 3/8	1 1/2	1 5/8	1 3/4	1 7/8	2	2 1/8	2 1/4	2 3/8	2 1/2	2 5/8	2 3/4	2 7/8	3

Table No. 2

Thickness of Wall in Fractions of Inch	Thickness of Wall in Decimals of Inch	Sizes in Inches in Which Square Tubing is Available																								
....	.035	...	...	...	...	1/2	5/8	3/4	7/8	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
....	.049	...	...	...	...	1/2	5/8	3/4	7/8	1	1 1/8	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
....	.065	...	...	...	...	1/2	5/8	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	...	1 3/4	...	2	...	...	...	...	...	...	...	...
....	.083	...	...	...	...	...	...	3/4	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	...	1 3/4	...	2	...	...	...	...	...	...	...	...
....	.095	...	...	...	...	...	...	...	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	...	1 3/4	...	2	...	2 1/4	...	2 1/2	...	2 3/4	...	3
....	.109	...	...	...	...	...	...	...	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	...	1 3/4	...	2	...	2 1/4	...	2 1/2	...	2 3/4	...	3
....	.120	...	...	...	...	...	...	...	7/8	1	1 1/8	1 1/4	1 3/8	1 1/2	...	1 3/4	...	2	...	2 1/4	...	2 1/2	...	2 3/4	...	3
....	.134	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1 3/4	...	2	...	2 1/4	...	2 1/2	...	2 3/4	...	3
5/32	.156	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1 3/4	...	2		2 1/4		2 1/2		2 3/4		3
3/16	.188	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1 3/4	...	2	...	2 1/4	...	2 1/2	...	2 3/4	...	3
1/4	.250	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2 1/4	...	2 1/2	...	2 3/4	...	3

The fuselage is usually assembled in two or more parts; one of these parts is the tail section, one the cabin section and one a forward section, called the engine mount. In some plants, and in constructing large planes, these sections are assembled separately and then welded together. In many instances, the engine mounting is an entirely separate section of the fuselage connected to it with bolted joints.

Some of the jigs, including those used for welding ailerons, are arranged so that they will revolve, thus enabling the welder to conveniently reach both top, bottom and sides of all welds. The jigs, of course, will vary with every manufacturing plant and every model of plane. The more complete and accurate they are, the more accurate the completed framework will be. If they are arranged so that the welder has quick and convenient access to all parts of them, he will be able to weld with greater rapidity and to produce better results. Jigs should be arranged, so that several welders can work upon the framework at the same time.

Testing a Welded Airplane Fuselage

As welding progresses, care must be taken by the welder to see that the joints do not completely close a tube. If such is the case a one-eighth inch hole is drilled through the obstruction. This hole permits the free flow of oil through the members of the fuselage when finally tested. In testing, the front end of the fuselage is raised and hot linseed oil, heated to approximately 180 degrees Fahrenheit, is pumped into the tubing of the fuselage through a small tapped hole at the forward end. The hot oil flows through every member of the fuselage until it finally reaches the small drain opening at the lower end. By feeling the tubes, the tester can tell whether the hot oil has entered every member. A defect in a weld will, of course, quickly show up, because the oil will leak through very small openings. The oil inside of the tubing prevents rust and, therefore, lengthens the life of the tubes. When the test has been completed, the oil is drained away and the plugs replaced. At any future date oil can, in similar manner, be circulated through the members of the fuselage to protect the steel against corrosion. The fuselage tubing is protected on the outside by first sand blasting the tubes and afterwards covering them with special paint.

Job Sheet No. 20

Welding Thin Steel Tubing

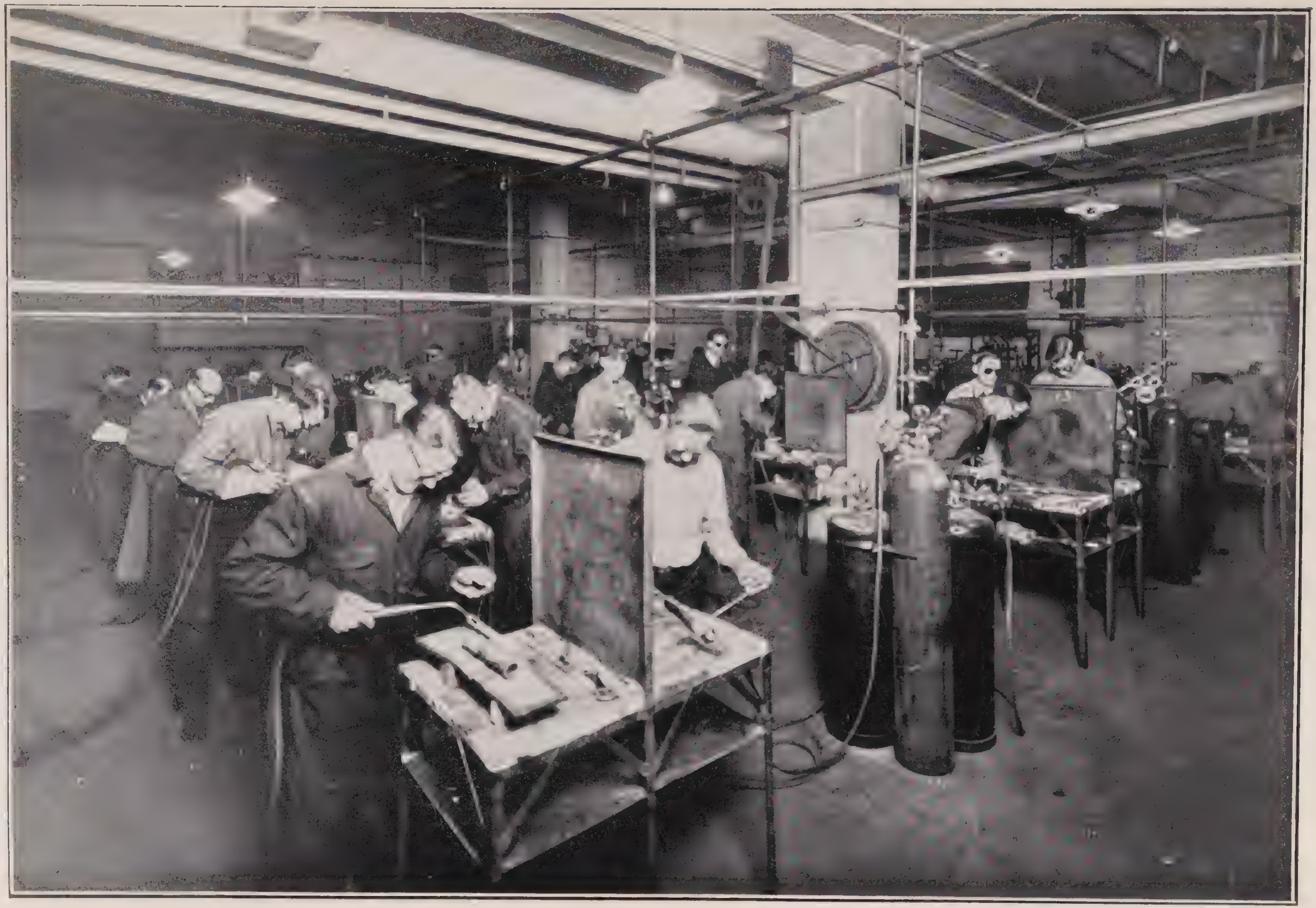
Aircraft welding, consists in the main of welding together very thin steel tubes. While the actual execution of the weld does not differ from the steel welds already made by the student, the preparation of the tubes to be welded together is radically different and the welder must use a great deal more care in handling the torch, so that he will not overheat and burn the tubing. Job sheet No. 20 is intended, therefore, to give the man who contemplates working in an aircraft factory some experience in the welding of tubing of this kind. The usual equipment will be required with the exception of the torch. If a small, light duty, airplane torch is available, this type of torch should preferably be used. No flux is required and a low carbon steel welding rod should be used. The student should obtain a generous supply of steel tubing, about one inch in diameter, with a wall .049 inches in thickness, or a little more than three-sixty-fourths of an inch.

The first work to be done is the making of the simple butt joint, as shown in Figure 14, Sketch No. 1. The ends of the pieces to be welded together should be cut square with the hack-saw and spaced about one-thirty-second of an inch apart. After this has been done, the pieces should be tack-welded together in three places. The spacing of the ends of the tubing permits the welder, when the weld is being made, to penetrate through to the bottom of the tubing. After the pieces have been tack welded together, the weld may be started at one of the tack welds and continued around the circumference of the joint. When the student masters the art of making these butt welds, he should then take other pieces of tubing and weld them together, using the fish-mouth weld, shown in Figure 14, Sketch No. 4. When preparing the ends of the tubes for this type of weld, the student should cut the ends of the tubing to the proper angle or as closely as possible, by means of a hack-saw and then use a file to smooth up the edges to make them fit exactly.

The student should continue making joints of the various types shown until he has familiarized himself with types of joints most commonly used, and is able to make a neat, sound weld without burning the tubing.

Questions:

1. What is the fuselage?
2. What is a fish-mouth weld?
3. Why is a fish-mouth weld used?
4. What is a lattice joint?
5. What is a reinforcing plate?
6. Why is chrome-molybdenum steel tubing used in fuselage construction?
7. What kind of welding rods should be used in welding chrome-molybdenum tubing in aircraft?
8. Why should jigs be used in airplane welding?
9. How are welds in aircraft construction usually tested?
10. What is one point which the welder must remember when entering the field of aircraft welding?



Photograph of one of the Evening Classes in Welding at the Dunwoody Industrial Institute, Minneapolis, Minn.

Useful Equipment Which Can Be Made in a Welding School

The three photographs on this page illustrate three welded articles, which can be made up in a welding school. These will hold the interest of the student in welding and at the same time produce useful, practical articles. Sheet steel and welding rods are the only materials required. The photograph to the left shows a combination kitchen stool and step ladder, made entirely of sheet steel with all joints welded. The height of the ladder is twenty-five and one-half inches. The top is twelve inches by sixteen and one-half inches. The distance between the legs is eight inches at the ends and thirteen and one-quarter inches at the sides.

In the lower left hand corner a steel humidifier is shown, having a water capacity of approximately three quarts, and being fifteen inches in length, eight inches in width and three and one-half inches in height.

The lower right hand photograph illustrates a shoe-polishing stand. This is all welded and made entirely of sheet steel. The height is fourteen inches, the length between the extended legs seventeen inches, and the width between the legs ten inches.

Part II

Part II

Chapter No. 1

Outline of Laws, Codes and Rules Pertaining to Welding

PART No. 2 of this book includes reference material and data which is a necessary part of the study of welding, but it is not expected that the student will try to learn all of it during his study of the course in welding. To this part of the book has been added a charter on Arc Welding to give the oxy-acetylene welder a knowledge of this process. Part No. 2 is intended to supplement the knowledge of the subject of welding and cutting gained from the previous twenty lessons, and to provide the student with reference material, to which he may have access, when he requires the data, tables and other information set forth.

Laws, Codes and Rules

In the Second Edition of this book State boiler laws were given in this chapter, and in other chapters parts of the Boiler Code and the Regulations of the Fire Underwriters were printed in full. So many other laws, codes and rules have now been written, and changes occur so often, that it is considered better to list the present codes and give a brief description of each rather than to print them all in full. This would make a volume in itself. If the welder requires any of these codes he will want the latest edition and can obtain copies from their various sources.

Regulations of the National Board of Fire Underwriters for the Installation and Operation of Gas Systems for Welding and Cutting

This is one of the more important regulations for the oxy-acetylene welder. The rules tell him how acetylene generators and welding and cutting equipment must be installed to be permitted by the Underwriters in insured buildings. It is not enough to merely purchase Underwriters approved or labelled equipment, but this equipment must be installed and used in accordance with these regulations to fully meet their requirements. These rules refer particularly to acetylene generator houses and their construction, to the operation and maintenance of stationary acetylene generators, to the operation and location of portable acetylene generators, to service piping systems for all gases, to the manifolding of cylinders to headers for shop pipe line supply systems, to the storage of oxygen and acetylene cylinders and calcium carbide, to welding equipment and to general precautions. Copies of these regulations may be obtained from the National Board of Fire Underwriters, 85 John St., New York City, or from branch offices in other cities.

American Society of Mechanical Engineers Boiler Construction Code

This code was introduced in 1914 by the Boiler Code Committee of the Society to standardize and control the construction of steam boilers to insure their safety. From time to time the code has been revised to meet the progress of industry and as welding developed the code was changed to include this process as a means for joining the parts of the boiler. Steam boilers are ordinarily divided into two main classes, high pressure, or power boilers, and low pressure, or heating boilers. Low pressure boilers have a maximum pressure limit of 15 lbs. per sq. in. while high pressure boilers are those exceeding this pressure and used for general power purposes. Low pressure boilers are divided into two general classes, steel plate boilers and cast iron boilers. High pressure boilers are likewise divided into two classes, miniature boilers, having a diameter not exceeding 16 inches and a length not exceeding 42 inches, and larger boilers used generally for power installations.

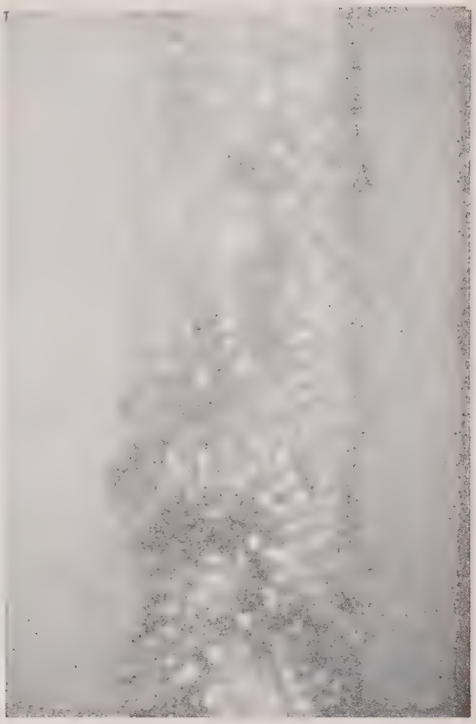
The boiler construction code, under which these boilers are constructed is divided into several sections as follows:

Power Boilers
Material Specifications
Locomotive Boilers
Low Pressure Heating Boilers
Miniature Boilers
Rules for Inspection
Care of Power Boilers
Unfired Pressure Vessels
Rules for Qualification of
Welding Process and Testing
of Welding Operators

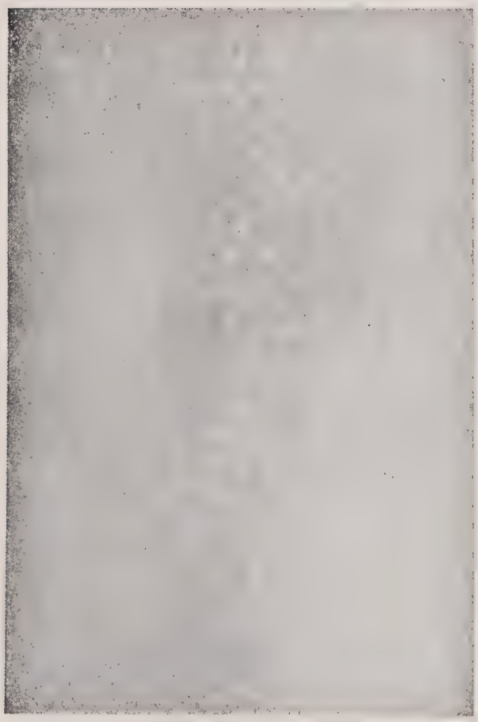
Unfired Pressure Vessel Section

When tanks or vessels are subject to pressure, without fire, they are called unfired pressure vessels. Air tanks, for the storage of air under pressure, would come under this classification, for example. Such tanks, if the pressure exceeds ap-

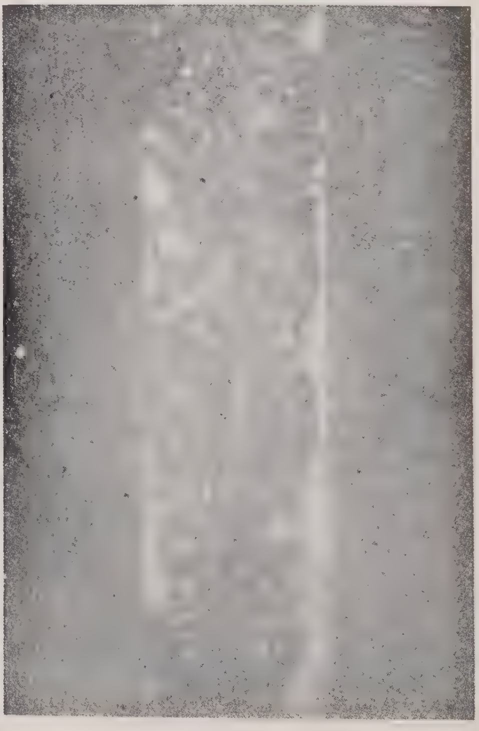
Radiograph No. 1—Excellent, or Ideal, Weld.



Radiograph No. 3—Porous and Unacceptable Weld.



Radiograph No. 2—Porous, but Acceptable, Weld.



Radiograph No. 4—Defective Weld Along Wall of Joint. Not Acceptable.

proximately 15 lbs. per sq. in., are subject to the requirements of this section of the code.

The code divides pressure vessels into three classes, called U-68, U-69 and U-70 vessels. Formerly the U-68 vessels were called Class 1, U-69 Class 2 and U-70 Class 3. U-68 vessels are built under the most regid requirements, including the testing of specimens of welds taken from the vessel during construction, by means of test plates attached to the vessel at each end of the longitudinal seam; examination of the welded seams by means of X-ray photographs, such as those shown on another page; hydrostatic and hammer tests; stress relieving by heating the vessel to 1100 to 1200 degrees in a furnace and last, but perhaps most important very rigid testing of all welders who work on the job. Welders are required to weld test specimens which are broken or bent, in various tests to determine their strength, ductility, imperfections, etc. Furthermore the process by a series of tests of specimens must be proven adequate to meet the requirements of the code. U-68 vessels may be used under the pressures and temperatures for which they were designed, but their use is not restricted in any way.

U-69 vessels are constructed under slightly less rigid rules and therefore are restricted to a maximum of 400 lbs. pressure and 700 degrees of temperature.

U-70 vessels are constructed under still less rigid conditions and are therefore limited to 200 lbs. pressure and 250 degrees of temperature.

It should be understood that all of these vessels are designed in accordance with definite rules which give the thickness and grade of steel for given diameters or pressures. This is accomplished by formulae and tables of the strengths of welded seams allowed and percentages of efficiency. This is a very brief description of a complicated code which requires much study to thoroughly understand it.

Many of the states have made the boiler code state law and other states, which have developed and printed their own codes, have patterned these codes largely on the requirements of the boiler code. The insurance companies, who insure boilers, rely on the boiler code for their safe construction.

The boiler code is published in its entirety bound in book form. The unfired pressure vessel section and some of the other sections are published separately in pamphlet form. Full information about the book, the pamphlet sections and their cost can be obtained by writing to the American Society of Mechanical Engineers, 29 West 39th Street, New York City.

A.P.I.-A.S.M.E. Code

In the petroleum industry many welded vessels are used under very high pressures and temperatures, in many instances as high as 2,000 lbs. pressure per sq. in. and 1000 degree Fahr. temperature. These are extreme and very severe conditions, but they are common in the refining of petroleum into oils, gasolines and the many other petroleum products which are in common use today. In order to provide for the manufacture of such vessels the American Petroleum Institute and the American Society of Mechanical Engineers drew up a special code which is called the A.P.I.-A.S.M.E. code. Copies of this code can be obtained from the American Society of Mechanical Engineers, 29 West 39th Street, New York City, or from the American Petroleum Institute, 50 West 50th Street, New York City.

Requirements for Repairs by Fusion Welding on Boilers and Pressure Vessels

All welders should be familiar with the rules for repairs of boilers and pressure vessels because they are often requested to make such repairs and should know what may, and what may not, be done. The following rules have been established by the National Board of Boiler Pressure Vessel Inspectors of Columbus, Ohio. These rules are given in detail because it is important for the welder to realize that welding is not permitted in connection with the repair of steam boilers except under certain conditions. The rules follow:

Approved October 24, 1935

1. By "fusion welding" is meant a process of welding metals in a molten, or molten and vaporous, state without the application of mechanical pressure or blows. Such welding may be accomplished by the oxy-acetylene or oxy-hydrogen flame or by the electric arc. Thermit welding is also classed as fusion welding.

2. A major repair by fusion welding, such as the repair or making of a new seam, the insertion of nozzles, or any repair involving the safety of a boiler or pressure vessel should be made in accordance with the section of A.S.M.E. Code governing the particular kind of vessel or kind of work to be done. The individual welders employed on such work must have passed satisfactory qualification tests as required by the A.S.M.E. Boiler or Unfired Pressure Vessel Code, and particular attention must be given the requirement that the position (flat, vertical or overhead) in which the welding is done on the test piece shall be the same as will be encountered in making the repair.

NOTE: The 1934 revision of the Unfired Pressure Vessel Code changes the designation and stamping of fusion welded vessels as follows:

"Class 1 vessels" to "vessel built in accordance with paragraph U-68"

"Class 2 vessels" to "vessel built in accordance with paragraph U-69"

"Class 3 vessels" to "vessel built in accordance with paragraph U-70"

3. NO WELDING REPAIRS SHALL BE MADE BEFORE AN INSPECTION HAS BEEN MADE BY AN AUTHORIZED IN-

SPECTOR AND THE METHOD OF REPAIR SANCTIONED BY HIM. If, in the opinion of the inspector, a hydrostatic test is necessary such test shall be applied when the work is completed.

4. Fusion welding on boilers or pressure vessels by unqualified welding operators will not be acceptable except in the cases specified herein where the safety of the boiler or pressure vessel does not depend upon the weld.

(a) Fusion welds not exceeding three feet in length will be permitted in a staybolted surface or one adequately stayed by other means so that, should the weld fail, the parts would be held together by the stays.

(b) Cracks in girth seams extending from the edge of the plate to the rivet hole may be fusion welded. All cracks that may be welded shall be properly prepared to permit fusion through the entire thickness of the plate. Similar cracks in a longitudinal direction and located between the rivet holes may also be fusion welded, provided the cracks do not extend more than 3 in. beyond the edge of the lap of the inner plate. Cracks extending from rivet hole to rivet hole on girth seams shall not be welded.

(c) Calking edges of girth seams may be built up by fusion welding under the following conditions: The thickness of the original metal between rivet holes and calking edge to be built up shall be not less than ¼ of the diameter of the rivet hole and the portion of the calking edge to be replaced shall not exceed 30 in. in length in a girthwise direction.

(d) Prior to making any repairs to girth seams by fusion welding the rivets shall be removed over the portions to be welded and for a distance of at least 6 in. beyond each such portion. After repairs are made the rivet holes shall be reamed before the rivets are redriven.

(e) When external corrosion has reduced the thickness of plate around handholes to an extent of not more than 40% of the original thickness and for a distance not exceeding 2 in. from the edge of the hole, the plate may be built up by fusion welding.

(f) Stayed sheets which have corroded to a depth of not more than 40% of their original thickness may be reinforced or built up by fusion welding. In such cases the stays and staybolts shall come completely through the reinforcing metal and the original ends of the staybolts shall be plainly visible to the Inspector. When necessary to replace stays and staybolts, they shall comply with the requirements of the A. S. M. E. Code.

(g) In fire tube boilers where tubes enter flat surfaces and the tube sheets have been corroded or where cracks exist in the ligaments, fusion welding may be used to reinforce or repair such defects. The ends of such tubes may be fusion welded to the tube sheets after they have been rolled and beaded. Such repairs for tube sheets and the welding in of tubes in the sheets shall not be permitted where such sheets form the shell or drum of a water tube boiler.

(h) Unreinforced openings in the shells or drums of boilers or pressure vessels, provided they do not exceed in diameter the sizes of unreinforced openings permitted by the A. S. M. E. Code (Par. P-268a or U-59a Revised) may be closed by the use of a patch or plate, at least 2 in. larger in diameter than the hole, placed on the inside of the drum or shell and sealed against leakage by fusion welding, preferably on both the inside and outside edges. Such patches shall not be set in the shell flush with the surrounding plate.

(i) Tubes of fire tube boilers may be re-ended or pieced by the fusion welding process provided such tubes are well distributed and their number does not exceed 50% of the total and further that there are no more than two circumferential welds in any one tube. Provided, however, that in fire tube boilers tubes that have been re-ended by the fusion welding process may be used in excess of 50% of the full number of tubes provided such re-ended tubes have been welded by operators who have demonstrated their ability to obtain sound and ductile welds. Satisfactory evidence of a welding operator's ability in this connection shall be obtained by having the welding operator make several sample welds between two pieces of boiler tubing, the welding to be done under the same conditions and by the same process as will be the case in the actual safe-ending of tubes. After such samples have been welded they shall be cut into longitudinal strips about 1 in. wide, the reinforcement of the weld on the outside, if any, ground off and the specimens then broken at the weld. This method of examination may be accomplished by gripping the specimen at the weld, in a vise, and the extended section driven backward with a hammer so that the weld will be opened at the root. To be satisfactory, welds broken in this manner shall be clean and properly fused through at least 90% of the thickness of the tube.

If more than 50% re-ended tubes are found in a boiler and it is impossible to have the welding operator who did the work make some sample welds for test, three tubes at various locations shall be removed from the boiler and the welds shall be subjected to the above test.

5. The repairing of tubes or headers in water tube boilers by fusion welding is not permitted.

6. Cracks in the shells or drums of power boilers, except as otherwise specified herein, shall not be welded.

7. The building up of grooved or corroded areas of unstayed internal surfaces, other than widely scattered pitholes, by means of deposited metal is not approved.

8. Leakage at riveted joints or connections must be carefully investigated to determine the cause of such leakage.

American Standards Association Tentative Code for Pressure Piping

This code was introduced in 1935 with the American Society of Mechanical Engineers as the sponsor. It covers power, gas and air, oil and district heating piping systems. It is intended to serve as a minimum standard for materials, design, dimensions, methods of fabrication, erection and testing of pipe systems and their component parts.

The code is divided into six sections as follows:

Section 1. Power Piping Systems.
Section 2. Gas and Air Piping Systems.
Section 3. Oil Piping Systems.
Section 4. District Heating Piping Systems.
Section 5. Fabrication Details.

Chapter 1. Pipe Hangers, Supports, Anchors, Sway Bracings and Vibration Dampeners.
Chapter 2. Pipe Joints Other Than Welded.
Chapter 3. Welding of Pipe Joints.
Chapter 4. Expansion and Flexibility Properties for Piping.

Section 6. Materials—Their Specifications and Identification.

There is a good deal of piping which is exempt from this code; for instance steam and hot water heating piping systems where the pressure does not exceed 15 lbs. per sq. in. Most heating piping systems in buildings would be included in this exemption.

Section 1 includes power piping systems to be found generally in steam generating plants, central heating plants, and industrial plants. It does not include gas, air and refrigerating piping, roof and floor drains, plumbing, sprinkler systems, piping for hydraulic pressure tools or equipment, sewers and industrial process piping.

Section 2 refers to gas and air piping systems. These include systems for conveying air, or fuel gas and illuminating gas, cross country transportation systems, piping in gas manufacturing plants, in gas or air compressing stations and in processing plants. Air piping systems under pressures of 30 lbs. per sq. in. and below are not included. Among other exemptions are casing, tubing and pipe used in gas or oil wells and natural gas field gathering systems located outside the boundaries of cities or villages.

Section 3 relates to oil piping systems used in the production, transmission and refining of petroleum.

Section 4 deals with district heating piping systems where the pressure is in excess of 15 lbs. per sq. in. These are the systems installed either above or under ground for the distribution of steam or hot water outside of buildings.

Section 5 covers fabrication details. Chapter 3 of this section is the chapter covering the mandatory minimum safety requirements for the welding of pipe joints. It also gives in detail the tests required of welding operators to prove that they are qualified to perform safe work.

Full details about this code can be secured from the American Society of Mechanical Engineers, 29 West 39th Street, New York City.

Code for Fusion Welding and Gas Cutting in Building Construction

This code was formulated by the American Welding Society and refers particularly to the use of welding for joining the members of the steel frames of buildings. Most cities have building codes some of which include welding as well as riveting for structural steel joints. Other codes, less recent, do not refer particularly to welding. Each year more and more cities are revising their building codes to include welding and in many instances this code is the basis of these revisions. Over 200 cities and municipalities have already adopted this code.

The principal sections and chapters of this code are as follows:

Section 1. General Application.
Section 2. Definitions.
Section 3. Materials.
Section 4. Permissible Unit Stresses.
Section 5. Design.
Section 6. Workmanship.
Section 7. Erection.
Section 8. Gas Cutting.

Appendix 1. Specifications for Filler Metal.
Appendix 2. Qualification Test for Operators of Welding Equipment.

Appendix 3. Recommended Welding Practices. Special Requirements for Arc Welds. Special Requirements for Gas Welds.

There is much very valuable material in this code including illustrations of types of joints, good and bad welds, common errors in making beads, position of electrodes and methods of making welds, table of plate thickness and current values, torch adjustment, methods for making gas welds, step method of multi-layer welding, etc. This code can be obtained from the American Welding Society, 33 West 39th Street, New York City.

Tentative Rules for Welding of Oil Storage Tanks

These rules were formulated by a committee of the American Welding Society working in close co-operation with a committee of the American Petroleum Institute. They are intended to apply to the construction of fusion welded bulk storage tanks of the above ground type for holding oil and liquid petroleum products operating generally at atmospheric pressure. They are not intended to apply to tanks containing petroleum products that will produce a vapor pressure appreciably above a few ounces. The same general design of storage tank, as referred to in the rules, may be used for higher pressure purposes if a dome, or umbrella shaped roof, is used and the shell is anchored to the foundation.

The rules are written with special reference to the application of fusion welded construction to cylindrical tanks on vertical axes, but of such diameters that they can not be shop constructed and shipped by cars or trucks. They are intended to prescribe safe requirements for such welded tanks. Full information can be obtained about these rules by writing to the American Welding Society, 33 West 39th Street, New York City.

Specification for the Design, Construction, Alteration and Repair of Highway and Railway Bridges by Fusion Welding

This specification was drawn up by a committee of the American Welding Society and issued in April, 1936. It has been approved by the American Railway Engineering Association and has been published as an appendix in the 1938 Edition of the American Association of State Highway Officials Bridge Specifications. The latest revised edition is that of 1938 and copies can be procured from the American Welding Society.

Rules for the Welding of Gravity Tanks, Tank Risers and Towers

These rules were formulated by a joint committee of the International Acetylene Association and the American Welding Society. They are intended to apply to the construction by fusion welding of steel storage tanks such as are used for the supply, by gravity, of water for fire protection purposes. They cover the construction of tank risers and also the fabrication of structural supporting towers for such tanks. The rules prescribe design, fabrication and erection requirements which it is believed will insure safe tank and tower construction.

The rules are divided into nine sections headed as follows: Scope; Definitions and Symbols; Materials; Qualification of Welding Processes and Testing of Welding Operators; Design; Fabrication; Erection; Inspection; Testing and Repairing. A revised edition of the rules was published in May, 1938, in the Welding Journal of the American Welding Society. Full information can be obtained from the Society.

Welding Rod and Electrode Specifications

The first specification of the American Welding Society covering welding rods and electrodes was issued April 1, 1920, and a revised edition was published May 1, 1921. This specification classified welding rods and electrodes by their chemical content, that is by the percentages of carbon, manganese, silicon, phosphorus and sulphur which the steel contained. They ranged from low carbon up to high carbon steel and excluded any steel made by the puddling process, such as wrought iron. They also included specifications for cast iron welding rods. Manganese steel rods, and rods for welding yellow brass, manganese bronze, copper and aluminum.

After a number of years of use of this specification it was found better practice to specify welding rods and electrodes by the physical properties of the weld metal deposited by the rod or electrode, rather than by their chemical properties. Other specifications were therefore written, published and tried out in actual experience. Seven years of labor by the Filler Metal Specifications Committee brought about the issuance of a specification for Iron and Steel Filler Metal that has been adopted and published jointly by the American Society for Testing Materials and the American Welding Society. This is the specification generally recognized by the welding industry. Its serial designation is A 205-37 T and was issued in 1937. It grades the steel for welding rods and electrodes in accordance with Table 1 and then specifies methods for making welded specimens and how they are to be tested. The specification also illustrates with photographs acceptable and unacceptable fillet welds.

Copies can be obtained from the American Welding Society or the American Society for Testing Materials, 260 South Broad Street, Philadelphia, Pa.

Marine Code for Fusion Welding and Gas Cutting

This code has been prepared by the American Welding Society. It is subdivided as follows:

Part (A) General Application.

Part (B) Rules for Fusion Welding of Drums and Shells of Marine Boilers and Pressure Vessels.

Part (C) Rules for the Repair of Marine Boilers and Pressure Vessels.

Part (D) Rules for the Fusion Welding of Hulls and Hull Parts.

Part (E) Rules for the Repair of Hulls by Fusion Welding.

Part (F) Rules for Fusion Welding of Marine Piping Installations.

These headings are self explanatory and no attempt will be made to give further details about this code. Full information can be obtained by addressing the Society.

Code for Fusion Welding and Gas Cutting in Machinery Construction

These rules have been formulated by the American Welding Society and are intended to cover the same scope for machinery construction as the code for fusion welding and gas cutting in building construction. Qualification tests for welders are provided and high standards required for fusion welding. Provision is made for gas cutting of the members and parts before welding.

Symbols

Of great importance to all welders is the bulletin on Symbols published by the American Welding Society. These symbols have been adopted by the various technical bureaus of the United States Navy, have been offered to the American

Standards Association with recommendation for adoption as an American Standard and are utilized in many draughting rooms in manufacturing plants for representing on drawings the exact type and size of welds required for the structure. They are really a short hand method of explaining to the welding engineer, foreman and operator what would otherwise require long and complicated notes and explanations on the drawing. Every welder must be familiar with these symbols if he is to properly read blue prints of structures where welding is required.

Association of American Railroads Code of Rules

These rules apply particularly to the gas and electric welding of railroad cars. They must be complied with if welding is to be done upon railroads. Welders who do this kind of work are, however, in the employ of the railroads, as a rule, and, therefore, under the jurisdiction of a foreman or engineer. The Chicago office of the Association is at 59 East Van Buren Street, Chicago, Ill.

TABLE I.—TENSILE REQUIREMENTS FOR DEPOSITED METAL.

Grade	Base Metal	Treatment of Welded Specimen[3]	All-Weld Tension Test: Tensile Strength, min., lb. per sq. in.	All-Weld Tension Test: Elongation in 2 in., min., per cent
No. 2	A.S.T.M. A 70 Firebox quality steel plate,[1] tensile strength 55,000 lb. per sq. in., min.; or A.S.T.M. A 7 Steel for bridges,[2] tensile strength 60,000 lb. per sq. in., min., with carbon not over 0.25 per cent and manganese not over 1.00 per cent; or equivalent steels.	stress-relieved	80 000	20[4]
		non-stress relieved	80 000	15[4]
No. 4	same as for Grade No. 2	stress-relieved	75 000	20[4]
		non-stress-relieved	75 000	15[4]
No. 10	same as for Grade No. 2	stress-relieved	60 000	25
		non-stress-relieved	60 000	20
No. 15	same as for Grade No. 2	stress-relieved	60 000	20
		non-stress-relieved	60 000	17
No. 20	same as for Grade No. 2	stress-relieved	52 000	10
		non-stress-relieved	55 000	7
No. 30	same as for Grade No. 2	stress-relieved	45 000	7
		non-stress-relieved	47 000	5
No. 40	same as for Grade No. 2	stress-relieved	45 000	5
		non-stress-relieved	47 000	3

[1] See Standard Specifications for Carbon-Steel Plates for Stationary Boilers and Other Pressure Vessels (A.S.T.M. Designation: A 70) of the American Society for Testing Materials, 1936 Book of A.S.T.M. Standards, Part I, p. 56.

[2] See Standard Specifications for Steel for Bridges (A.S.T.M. Designation: A 7) of the American Society for Testing Materials, 1936 Book of A.S.T.M. Standards, Part I, p. 1.

[3] Stress-relieving where called for in these specifications is for the purpose of developing the fundamental properties of the weld metal unaltered by locked-up stress. Values obtained from stress-relieved welded specimens are about 5 per cent lower in tensile strength and 10 to 20 per cent higher in ductility than those of non-stress-relieved specimens. The fact that a filler metal test requires stress-relief signifies only that it must develop the strength required regardless of stress-relief, and not that stress-relief must always be used in actual work. Stress-relieving shall be within the range of 1100 to 1200 F. for 1 hr. per 1 in. of thickness. Gas-welded specimens may be heat-treated at higher temperatures than the temperature specified above for stress-relief.

[4] It is immaterial how these high physical properties are obtained, that is, whether by carbon-steel filler metal with manganese and silicon contents or by the use of some other alloying elements, but the total amount of such other elements shall be less than 4 per cent.

Underwriters Laboratories' Standards for Construction and Performance of Stationary and Portable Acetylene Generators

These rules have been formulated to assure the safe construction of acetylene generators. They provide definite and specific requirements for the design and materials used for generators and methods of manufacture. They are of especial use to manufacturers of generators, but are mentioned here because of the attempts of welders occasionally to build their own acetylene generators without the necessary engineering knowledge required to properly and safely design and construct a generator. There are similar rules for the manufacture of welding regulators, torches, etc.

These rules do not give information relating to the installation and use of welding and cutting equipment and acetylene generators as this will be found in the rules, heretofore mentioned, under the heading Regulations of the National Board of Fire Underwriters for the Installation and Operation of Gas Systems for Welding and Cutting.

Copies can be obtained from the Underwriters' Laboratories, 208 East Ohio Street, Chicago, Ill.

Department of Commerce Steamboat Inspection Service

This is a code of rules referring particularly to vessels under the jurisdiction of the United States, both on the Great Lakes and rivers of the country, and in the ocean. They apply to the design, construction, installation, repair and inspection of boilers, piping systems, etc. Copies of this code can be obtained from the Bureau of Navigation and Steamboat Inspection, Washington, D. C.

Heating Piping and Air Conditioning Contractors National Association

These specifications refer to the fusion welding of steel and wrought iron pipe used generally for heating purposes in buildings. They cover preparation, workmanship and the qualification of welders and include many illustrations, tables and details of such piping systems. Information may be obtained by writing the Association at Rockefeller Center, 1250 6th Ave., New York City.

There are other rules and regulations, but the principal ones are mentioned in this chapter. Information covering specific instances where welding is covered by rules or regulations can be obtained by writing to the publishers of this book.

Chapter No. 2

Firebox Welding Practice

IN this discussion it is assumed that the student has carried on the work described in the twenty job sheets, has completed the study of the twenty lessons and is, therefore, a skilled welder. It will, under these circumstances, be unnecessary to further discuss the details of welding, and it is assumed that the welder can and will make sound welds.

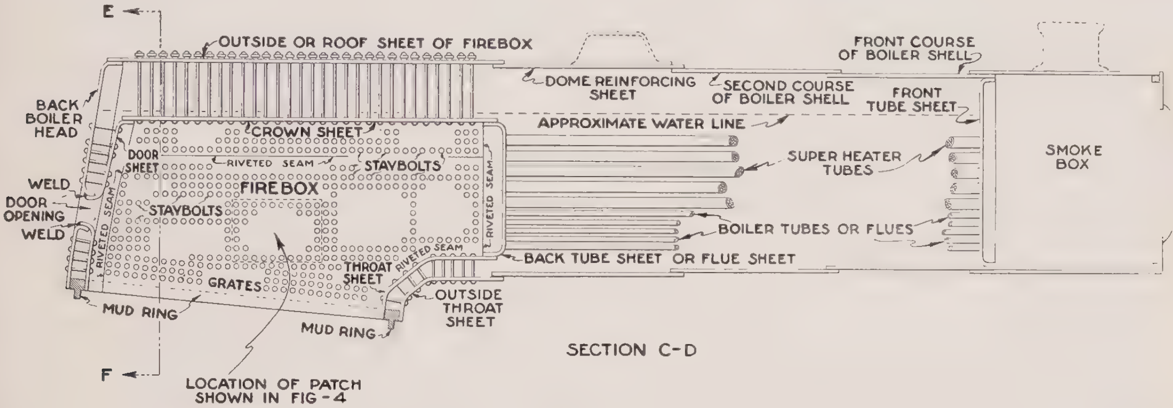

E
OUTSIDE OR ROOF SHEET OF FIREBOX
BACK BOILER HEAD
CROWN SHEET
DOOR SHEET
RIVETED SEAM
STAYBOLTS
FIREBOX
WELD
DOOR OPENING
WELD
RIVETED SEAM
STAYBOLTS
RIVETED SEAM
THROAT SHEET
RIVETED SEAM
GRATES
MUD RING
MUD RING
OUTSIDE THROAT SHEET
F
LOCATION OF PATCH SHOWN IN FIG-4
DOME REINFORCING SHEET
SECOND COURSE OF BOILER SHELL
FRONT COURSE OF BOILER SHELL
FRONT TUBE SHEET
APPROXIMATE WATER LINE
SUPER HEATER TUBES
SMOKE BOX
BOILER TUBES OR FLUES
BACK TUBE SHEET OR FLUE SHEET
SECTION C-D

Figure 1—General Sectional View of a Firebox and Boiler of the Locomotive Type. Various Sheets and Parts Which Make Up This Drawing Are Indicated by the Names Ordinarily Used for Them.

An outline of the laws, codes and rules of the United States was given in Chapter 1. In this chapter will be discussed the welding practice permitted upon fireboxes of boilers of the locomotive type. While the illustrations show a boiler for a large modern locomotive, the smaller boilers encountered by the welding shop owner, used as stationary power boilers, boilers for road rollers, or small locomotive boilers around mines or quarries are constructed in generally similar manner and rules and practice which apply to the larger type of boiler illustrated also apply to these other types.

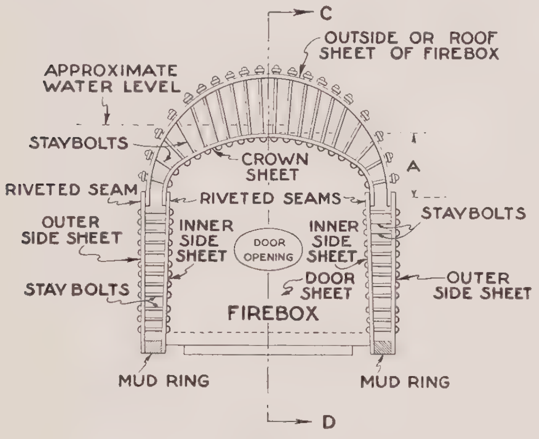
The principles involved are the same, and if the welder knows how to proceed with the larger locomotive boiler, he will be able to adapt this knowledge to any other boiler which he encounters.

It should be understood that these are high pressure boilers, that is, boilers in which the steam pressure is in excess of fifteen pounds per square inch. They, therefore, are governed by the power boiler section of the A.S.M.E. Boiler Construction Code. This section was revised July 7, 1931, to permit the manufacturing of new power boilers with welded shells. These new rules, covering welding, are rigid, requiring thorough, non-destructive tests, including X-ray tests of the welded seam. It is also required that the boiler shell be stress-relieved by heating, after welding.

These rules are generally similar to those governing the welding of unfired pressure vessels mentioned in Chapter 1, but refer particularly to boilers. They do not materially change the present rules, nor the general practice pertaining to welded repairs.

The student should now refer to Figures 1 and 2, which will help him to understand the general construction of the firebox of a locomotive type boiler. It is necessary that he be familiar with this construction in order to understand the wording of the boiler laws, because they are constantly referring to the various sheets and parts of the firebox and the boiler by their technical names. Figure 1 is a general section of a locomotive boiler and firebox. Figure 2 is a section taken through the rear portion of the boiler and firebox and looking toward the fire-door in the rear end of the boiler. Both of these views show as clearly as possible the various sheets or plates from which the boiler and the firebox are constructed. They also show the staybolts located closely together over practically all of the surfaces of the sides, rear end and top of the firebox to hold the firebox in position within the boiler and to prevent the pressure from crushing the firebox or rupturing the boiler shell.

At the base of the firebox is what is known as the "mud ring." This is really a foundation ring of cast steel, which is the main foundation or base of the firebox and boiler structure in this portion of the locomotive. The firebox itself is the internal box-like structure rising from the mud ring and constituting that portion of the boiler under which the grates are located and where the fire burns. In Figure 20 a sketch is shown of a completely welded firebox of this type. The seams of all fireboxes are not welded, however, as many boilers of all kinds have been constructed with riveted seams. Figures 1 and 2 illustrate a boiler where all of the seams are shown as riveted seams. In these figures each sheet or plate, from which the firebox and boiler are made, are marked with the generally accepted names which apply to them. By close reference to these two figures the student will be able to follow the text without difficulty.



SECTION E-F

Figure 2—Cross Sectional View of Firebox Looking Toward Fire Door.

Boiler welding as it applies to high pressure boilers is really not a correct name, because welding of the boiler itself is not permitted by the boiler code, except in very limited instances. It should be called "firebox welding," because the greater portion of the welding permitted in the boiler structure lies in the firebox itself. The inner and outer walls of the firebox, studded with staybolts, are generally called "Stayed Surfaces" and the staybolts greatly assist in strengthening these walls. For this reason, welding is allowed in this portion of the boiler where it is not allowed in the boiler shell itself which is an unstayed surface and, therefore, does not possess the strength of the stayed surfaces of the firebox.

The forward end of the firebox is a tube or flue sheet, into which the fire tubes of the boiler are set and securely fastened. A similar tube sheet lies in the forward portion of the boiler and divides the boiler proper from the smoke box which is in the extreme forward end. The fire and heat pass from the firebox through these tubes to the smoke box.

These tubes and the entire firebox, including the crown sheet are submerged in water, which completely fills the boiler to a level about three inches above the highest point of the firebox.

There are, of course, many variations in design and many different details applying to these boilers, but generally speaking this is the type of construction which the welder will encounter in a large number of instances.

One of the first, and most important requirements of the Boiler Code in connection with power boilers, is that autogenous welding, or in other words, fusion welding, produced either by the oxy-acetylene torch or the electric arc shall only be used where the strain caused by the pressure in the boiler is carried by other parts of the structure and where the safety of the structure is not dependent upon the strength of the weld. Another requirement is that autogenous welding shall not be accepted in unsupported surfaces. It will be readily understood that these two rules limit the greater portion of welding, which is permitted, to the stayed surfaces of the firebox. The stayed surfaces are supported by the staybolts to other parts of the boiler and for this reason, a weld made in these surfaces is not subjected to anything like the pressure which might be set up if the weld were located where there were no staybolts. There should be no confusion, however, between the boiler itself and the smoke box of the boiler. As the smoke box is forward of the front tube sheet, it is not subjected to steam pressure and, therefore, is not classed in the same manner as the boiler shell itself.

The statement in the Code "Autogenous welding will not be accepted in unsupported surfaces" means distinctly that no welding will be permitted in the boiler shell of the boiler itself, or in any part of the boiler which is not supported by staybolts or other reinforcing structures. Another statement with reference to the boiler shell is as follows: "Autogenous welded-in patches in the shell of a boiler are prohibited, regardless of the size of such patches." Autogenous welding of cracks in the shell of a boiler are prohibited, unless such welding is only for the purpose of securing tightness and stresses on the parts are fully cared for otherwise. The student should refer particularly to the Requirements for Repairs by Fusion Welding on Boilers and Pressure Vessels printed in full in Chapter No. 1.

On the other hand, in the firebox of the boiler where the walls of the firebox are supported by staybolts, and a large portion of the strains are distributed by these bolts, patches and larger portions of the sheet may be welded in place. There is a good deal of welding which can be done in a firebox, of course, depending to a certain extent upon the local conditions, the inspectors, etc., but one specific provision is that welding shall not be done unless the weld is twelve inches below the water line. This rule prevents the application of patches to crown sheets. No welding is permitted on the crown sheet, including cracks and crown bolt holes, with the exception of the side sheets to the crown sheet, which seams are twelve inches or more below the top of the crown sheet and the seams between the flue sheet and the crown sheet and the door sheet and the crown sheet.

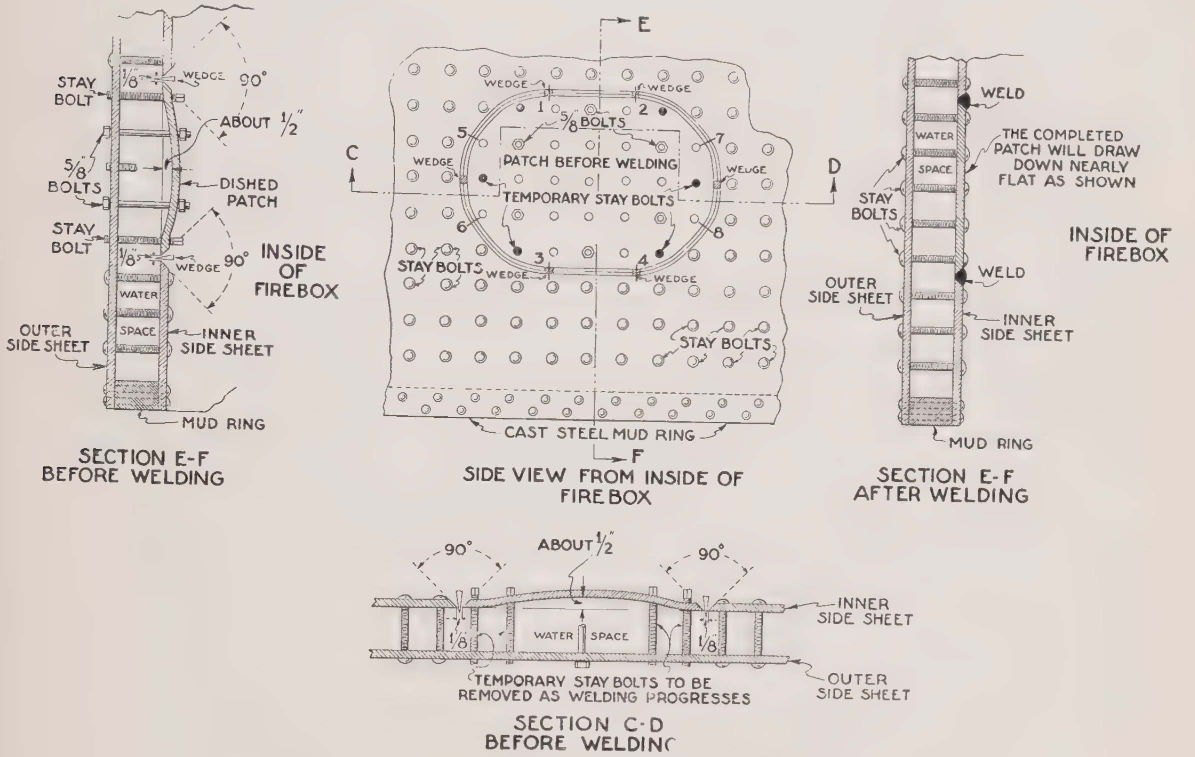

STAY BOLT
1/8"
WEDGE
90°
ABOUT 1/2"
5/8" BOLTS
DISHED PATCH
STAY BOLT
1/8"
WEDGE
90°
INSIDE OF FIREBOX
WATER
SPACE
OUTER SIDE SHEET
INNER SIDE SHEET
MUD RING
SECTION E-F BEFORE WELDING
E
WEDGE
WEDGE
1
2
5/8 BOLTS
5
7
C
WEDGE
PATCH BEFORE WELDING
WEDGE
D
TEMPORARY STAY BOLTS
6
8
3
4
STAY BOLTS
WEDGE
WEDGE
STAY BOLTS
CAST STEEL MUD RING
F
SIDE VIEW FROM INSIDE OF FIREBOX
WELD
WATER
SPACE
THE COMPLETED PATCH WILL DRAW DOWN NEARLY FLAT AS SHOWN
STAY BOLTS
INSIDE OF FIREBOX
WELD
OUTER SIDE SHEET
INNER SIDE SHEET
MUD RING
SECTION E-F AFTER WELDING
90°
ABOUT 1/2"
90°
INNER SIDE SHEET
1/8
WATER SPACE
1/8
TEMPORARY STAY BOLTS TO BE REMOVED AS WELDING PROGRESSES
OUTER SIDE SHEET
SECTION C-D BEFORE WELDING

Figure 3—A Dished Patch in the Inner Side Sheet of a Firebox of the Locomotive Type. Sections E-F Show the Patch Before Welding and After Welding. The Patch Is Dished to Offset the Contraction Forces, Which Would Otherwise Produce Strains in, or Break, the Sheet.

Boiler Flues

When boiler flues are welded into the flue sheet, the work is usually done with the electric arc process. The heat from a torch when welds are as close together, as they must be in welding the flues to the flue sheet, will usually distort the sheet and develop strains within the steel, which are very difficult to handle. The heat of the electric arc, while higher than that of the oxy-acetylene torch, is localized to a far greater extent, and for this reason does not raise the temperature of the surrounding metal to as great a degree as the torch. Therefore, the welding of flues in the flue sheet is confined by most railroads to the electric arc process. As a matter of fact, a large proportion of the firebox welding upon many of the railroads is accomplished by the electric arc. In much of this work, however, the specifications do not limit the process to the electric arc, but permit the use of either the oxy-acetylene or electric method as may be available at the point where the work is done, or may be preferred by the local authorities.

Firebox welding can be done to excellent advantage with the oxy-acetylene torch, and the oxy-acetylene welder operating a job shop may find, upon occasion, that he is called upon to accomplish repairs upon the fireboxes of high pressure boilers when the torch is his only means for accomplishing the work. The welder who is employed in a railroad shop will not have to decide these problems for himself, because the regulations of the railroads are very specific in all work accomplished and the welding supervisor or welding foreman will direct the work to be done, but where the welder must rely entirely upon his own judgment, he should, without fail, consult the local boiler inspector before proceeding with the job.

It is not proposed here to discuss the relative merits of the oxy-acetylene and electric processes for boiler welding, because there would be no advantage in doing so. The object of this Course of Instruction is to teach an oxy-acetylene welder to use his torch skillfully and correctly on those jobs which can be efficiently accomplished with the process. The electric arc may be applied in many places, where the torch may also be used, and both processes in the hands of skilled men will produce sound, strong welds. In some instances, like the welding of flues in the flue sheet, the electric arc will produce better results than the torch, and in such instances, the oxy-acetylene welder should not attempt to do the work with a torch, where the arc has been proved a superior method. In other instances, the torch has many advantages over any other process. The welder after a little experience in firebox welding will quickly determine these conditions for himself and use the process best adapted to the job at hand if the equipment is available.

Some of the various jobs which may be accomplished by the welding shop owner when he is requested to make repairs upon stationary or other high pressure boilers are discussed in this chapter and methods are given whereby he may accomplish this work to good advantage. These methods will not always follow the recommendations of the railroads for general firebox practice, because, in most instances, the railroads employ the electric arc process rather than the oxy-acetylene process for firebox work. If the job shop welder followed their exact recommendations for this work, he would not, as a rule, be able to produce as successful results as he would if he viewed the repair entirely from an oxy-acetylene standpoint.

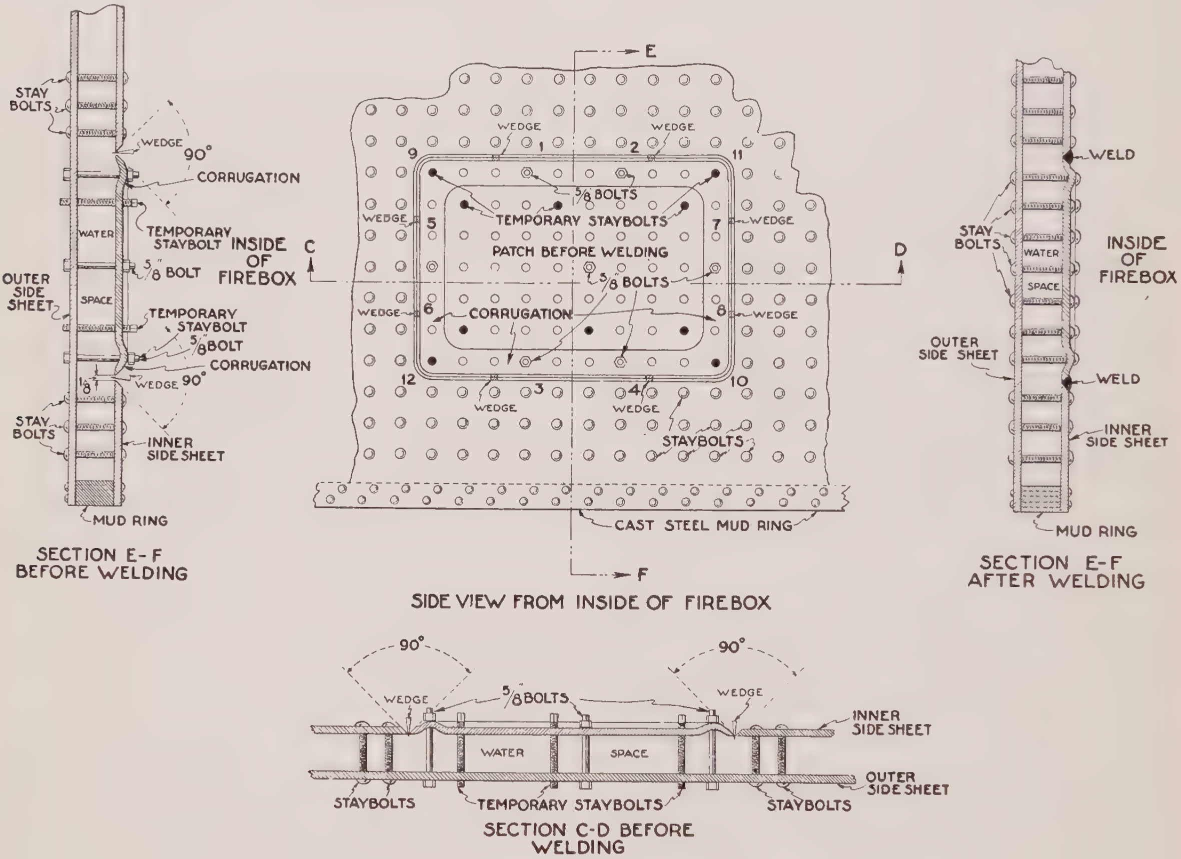

STAY BOLTS
WEDGE
90°
CORRUGATION
WATER
TEMPORARY STAYBOLT
5/8" BOLT
INSIDE OF FIREBOX
OUTER SIDE SHEET
SPACE
TEMPORARY STAYBOLT
5/8" BOLT
CORRUGATION
1/8"
WEDGE 90°
STAY BOLTS
INNER SIDE SHEET
MUD RING
SECTION E-F BEFORE WELDING
E
C
WEDGE
WEDGE
1
2
9
11
5/8 BOLTS
TEMPORARY STAYBOLTS
5
7
PATCH BEFORE WELDING
5/8 BOLTS
6
8
CORRUGATION
12
10
3
4
STAYBOLTS
CAST STEEL MUD RING
F
D
SIDE VIEW FROM INSIDE OF FIREBOX
WELD
STAY BOLTS
WATER
SPACE
INSIDE OF FIREBOX
OUTER SIDE SHEET
WELD
INNER SIDE SHEET
MUD RING
SECTION E-F AFTER WELDING
90°
90°
WEDGE
5/8" BOLTS
WEDGE
INNER SIDE SHEET
WATER
SPACE
OUTER SIDE SHEET
STAYBOLTS
TEMPORARY STAYBOLTS
STAYBOLTS
SECTION C-D BEFORE WELDING

Figure 4—A Corrugated Patch in the Inner Side Sheet of a Firebox of the Locomotive Type. The Thickness of the Sheets in Relation to the Diameters of the Staybolts Has Been Exaggerated to Better Show the Details of the Weld. The Corrugated Patch Has Many Advantages, and While More Expensive to Make Than the Dished Type, Is Usually Worth the Additional Expense, Especially When Oxy-Acetylene Welding Is Used.

The first repair which will be discussed in this chapter is the welding of patches in the inner side sheet of a firebox.

Welding Patches in Firebox Sheets

Where the sheets are corroded, or where there are several cracks between staybolts, it is better to make a repair by welding in a patch than it is to attempt to weld the crack, or to build up the corroded sheet. The location and size of this patch will depend entirely upon the condition of the sheet, but in general, the outline of the patch should be nearly circular in shape and sharp corners should be avoided.

The center line of the weld should always lie between staybolts, even if the outline of the patch must be made irregular to accomplish this purpose. The welding of staybolts to the sheets is prohibited, and if the weld were to be made through the staybolt hole, the hole would have to be redrilled and retapped. If the sheet is defective adjacent any staybolt hole, it is better to make the patch include another row of staybolts. This will be apparent if Figures Nos. 3 and 4 are studied. Figure 3 shows a dished patch and Figure 4 a corrugated patch. As stated heretofore, boiler work is usually done by the electric arc, and as the heat of the arc is confined within limited areas to a greater extent than the torch, there is less tendency of the sheet to warp or to become strained through the greater expansion and subsequent contraction caused by the torch.

As this Course of Instruction deals mainly with torch practice, the examples of boiler welding given in this chapter are designed specifically for oxy-acetylene welding, and the practice, therefore, differs somewhat from that generally recommended for the electric arc.

Figure 3 illustrates the application of a dished patch. The patch is shown in the inner side sheet of the firebox of a locomotive boiler. The lower line of the patch is three staybolt rows above the mud ring and the patch is five rows high and seven rows in length. The first step in the procedure of applying a patch of this kind is to mark upon the inner side sheet, where the center line of the weld is to be. This can be determined only by careful examination of the sheet to determine that part of the sheet which is sound and that part which should be replaced. With a chalk-mark, the outline of the patch should be indicated and with a cutting torch the operator should cut through the sheet along the chalk line.

The staybolts within the area of the patch should be cut out with the torch, as illustrated in Figures 16 and 17. Some welders recommend the holding of the torch at an angle of forty-five degrees to the surface of the plate in order to cut the bevel of the patch at the same time the patch is being cut out, but as this practice is difficult and usually results in irregular edges, it is believed better to hold the torch perpendicular to the surface of the plate and cut straight through the plate all the way around. The sheet may afterwards be bevelled with the torch to an angle of forty-five degrees, or the edge may be chipped away with a chipping hammer. If the torch is used, a chipping hammer should be subsequently applied, if necessary, to remove any slag or oxide which may have accumulated.

Cutting of staybolts is a very simple matter. As illustrated in Figures 16 and 17, the cutting torch flames are directed in line with the center line of the staybolt and the head of the staybolt heated until red hot. The cutting jet is then turned on, and as a hole is burned into the bolt, the torch head is turned at an angle and rotated to such an extent that the cutting jet will cut through the side of the staybolt, rather than continue directly through its center. The rotating movement of the torch cuts the staybolt off inside of the sheet and, if skillfully done, no damage will occur to the sheet itself.

When the staybolts have all been removed, the old pieces of the side sheet completely cut away and the edges of the sheets bevelled to an angle of forty-five degrees, a new piece is made to closely fit the opening. There should be from one-eighth inch to three-sixteenths inches of space allowed all the way around the perimeter of the patch. Some welders advocate a space of three-sixteenths of an inch, or even more, but it is obvious that if this space is too large, the weld metal will drip or run down on the inner side of the sheet, or there will be a projection of weld metal into the water space between the sheets. Furthermore, the wider this space, the more weld metal will be required to complete the weld. Therefore, it is important that this space be just wide enough to allow for expansion and one-eighth of an inch all the way around the patch is usually considered sufficient.

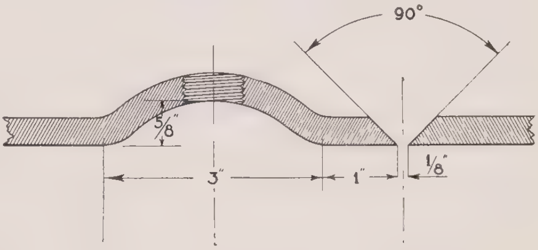


Figure 5—Details of Corrugation for Corrugated Patch. The Staybolt Holes May Come in the Center Line of the Corrugation, or They May Be Off Center to a Certain Extent. At the Corners the Corrugation May Come Between the Rows of Staybolts. These Details Will Depend Largely Upon the Location of the Weld. The Weld Itself Should Always Be Placed Between the Rows of Staybolts and Should Not Pass Through Any Staybolt Hole.

Wedges are useful in keeping the edges in their proper position and six of them for a patch of the size shown in Figure No. 3 will be of assistance. The illustration shows six temporary staybolts indicated by the solid black circles, which are used to hold the patch in position during welding. There are also six five-eighths inch common bolts slipped through the staybolt holes, which are used to draw down the dish in the patch, as may be required.

In preparing the patch the edges should be bevelled to an angle of forty-five degrees, and the patch should be dished toward the inside of the firebox approximately one-half inch. The amount of the dish will depend largely upon the size of the patch but it should be enough to take care of the contraction which will occur as the weld is completed.

The routine of procedure in making a weld of this kind depends to a large extent upon the operator. There is a wide variation in practice and many good boiler welders have their own preferred methods for welding. Some welders prefer to weld up and others prefer to weld down. For the beginner it seems good practice always to weld up, and this may also apply to a skillful welder, who is accustomed to welding on a horizontal surface, but is not so skillful in vertical welding. In welding down, great care must be taken to prevent the hot steel from the puddle from running down over the colder surface and forming a cold lap, or lamination, because of the lack of union between the weld metal and the metal of the sheet. An excellent procedure for the welding of the patch shown in Figure 3 is as follows:

Start welding at No. 1 and weld for about two inches toward No. 2, then stop welding at No. 1 and weld from No. 2 back to No. 1. Begin welding at No. 3 and weld for about two inches, then start welding at No. 4 and weld back to No. 3. Weld for about two inches from No. 5 toward No. 1 and then weld from No. 6 upward toward No. 5. In like manner proceed, beginning at No. 7, and then welding from No. 8 to No. 7 and so on from No. 5 to No. 1, then No. 4 to No. 8, from No. 7 to No. 2, and then from No. 3 to No. 6. This is a modification of what is often called the back-step method of welding, and may be skillfully used by an oxy-acetylene welder to distribute the heat over as much of the patch as possible without overheating any particular section.

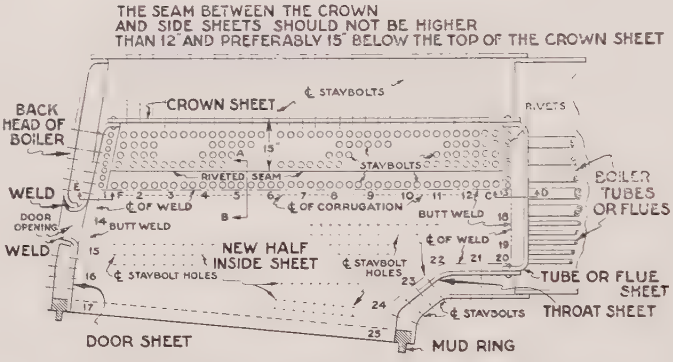


Figure 6—Welding a Half Side Sheet. The Vertical and Horizontal Seams Are Both Butt Welds, Which Require Bending the Flanges of the Door Sheet and the Flue Sheet to Meet the New Section Being Welded in Place.

As welding progresses the staybolts should be removed and the five-eighths inch bolts can be used to draw down upon the dished patch. The object is to place as much compression upon the weld as possible, which will offset the pull or draw upon the weld, as contraction takes place. The dish of the patch should draw out nearly flat. It will not, of course, be a perfectly flat piece, as shown in the section, E-F, Figure 3, after welding, but it will approach this condition to a large extent.

The location of the staybolts and the five-eighths inch bolts, used to hold the patch in position during welding, will depend upon the individual patch and the experience and preference of the welder. No hard and fast rules can be laid down for this particular procedure and it is thought better to permit a good deal of latitude in this practice.

In fact, specific rules for boiler welding would probably be a mistake, because there are so many conditions which vary that the welder must of necessity use his own good judgment in making a repair, based upon the condition of the boiler sheets, the location of the patch and other facts which may govern these specific instances, which he is considering.

Corrugated Firebox Patches

While the dished patch may serve in certain instances, and is certainly more easy to prepare than the corrugated patch, there are many welders who prefer to take the time and trouble to corrugate a patch, rather than to depend upon the dish only, to take care of contraction strains. It will be clearly understood that a corrugation all around the patch is likely to be of greater assistance in compensating for contraction strains than the dished construction, particularly because of the practice of heating along the center of the corrugation after the weld adjacent this section has been made.

Figure 4 illustrates a patch of the corrugated type. The shape of the patch may vary according to local conditions, but the corrugation is formed in the patch paralleling closely the perimeter of the patch. Details and dimensions of the corrugation are given in Figure 5. These are approximate and may be varied to suit local conditions. The procedure in welding this type of patch is generally similar to that already described for the dished patch. Welding may begin at No. 1 and the weld continued toward No. 2 for about two inches. The torch should then be moved to No. 2 and the weld made back to No. 1. A two-inch weld may then be made at No. 3 and the torch moved to No. 4 and the weld made back to No. 3. In similar manner welding progresses at No. 7 and then from No. 8 to No. 7, at No. 5 and then from No. 6 to No. 5 and so on alternating back and forth from side to side until the entire weld is completed.

After each section of the weld has been completed, the corrugation adjacent this section should be heated along the center of the corrugation to a red heat and this should be continued until the entire weld is done. Welding of the vertical sides of the patch may be in a downward direction, but as stated heretofore, in most instances it is preferable to weld up.

The exact procedure as described may not always be followed, depending upon the preference of the individual operator. Sometimes a sheet may expand too much at one particular point, and it may be necessary to vary the routine to offset this condition. The five-eighths inch bolts and the staybolts may be removed as the welding of the patch continues, and the wedges may either be removed or welded in place. Sometimes pinch bars may be found convenient in keeping the sheets in line if they warp horizontally toward the water space. It may also be necessary to hammer the sheets back if outward warping occurs. Good judgment and care will enable a skillful welder to make a very satisfactory job of a patch of this kind.

In cutting and fitting this patch, care should be taken, as described for the dished patch, to allow a space of one-eighth of an inch all the way around the patch. In building up the weld slightly thicker than the thickness of the sheet, care should be taken that this reinforcement is not too great. It should not exceed three-sixteenths of an inch, because of the possibility of overheating by having at the weld a section much thicker than the balance of the sheet.

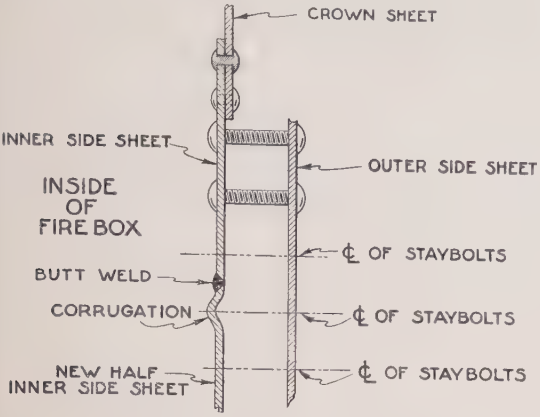

CROWN SHEET
INNER SIDE SHEET
INSIDE OF FIRE BOX
OUTER SIDE SHEET
℄ OF STAYBOLTS
BUTT WELD
CORRUGATION
℄ OF STAYBOLTS
NEW HALF INNER SIDE SHEET
℄ OF STAYBOLTS

Figure 7—This Sketch Shows a Sectional View Indicated by the Lines, A-B, of Figure 6. The Horizontal Butt Weld Between the Old Part of the Inner Side Sheet and the New Half of This Sheet Is Shown Together with the Horizontal Corrugation Immediately Below It.

Welding a Half Side Sheet in a Firebox of the Locomotive Type

When the defects in the inner side sheet of the firebox are too great to permit of patching, or when several patches have already been placed in the sheet, it may be desirable to renew the entire lower portion of the sheet. Some railroads require that when two patches have been applied to a side sheet, exclusive of mud ring corner patches, a new half sheet must be installed rather than welding in another small patch.

Figure 6 illustrates the procedure for the application of a new half inner side sheet. The staybolts of the sheet are all cut out, and removed. The rivets are cut out between the inner side sheet and the door sheet, and the inner side sheet and the flue and throat sheets. A horizontal cut is made between staybolts where the weld is to be made, as indicated by the line 1-13. The rivets between the old section of the inner side sheet and the mud ring are removed, and this entire section of sheet removed from the firebox. The flanges of the door sheet, the flue sheet and the throat sheet are cut off along the inner edges of the rivet holes, as shown at 1-17 and at 13-20, also at 20-25. This removes the rivet holes from these flanges and the edges of the flanges are bevelled to angles of forty-five degrees. A butt weld is made between the new piece of sheet and the flange itself.

It is necessary, however, to bend the flange in towards the water space, in order that it may line up with the new sheet. A little thought will make this clear. The new section of sheet is located in the same position as the old riveted sheet, in line with the upper portion of the sheet which remains in the firebox. A butt weld is made along the line 1-13 after the old sheet has been bevelled to an angle of forty-five degrees and the new sheet bevelled in like manner. At the corner, 1, between the new sheet and the flange of the door sheet, and at the corner, 13, between the new sheet and the flange of the flue sheet, there is, therefore, a somewhat complicated joint which necessitates bending these flanges as shown in Figure 8.

This is not difficult to do, and enables butt welds to be made between the flanges of the door sheet and the flue sheet instead of lap welds which are not usually desirable. Butt welds are preferred to lap welds, because the lines of stress in the steel pass directly through the weld and are not diverted, as they must be in a lap weld. Lap welds are likely to develop inequalities and concentration of stresses, which are not usually satisfactory.

Figure 8 illustrates these corners so that they will be clearly understood. The ninety degree vee between the old portion of the inside sheet and the new section is cut, along the horizontal seam until this seam meets the flange. The flange has been cut out as shown and bevelled and the edge of the flange is bent down to meet the new section of the sheet, as shown in section XY of Figure 8. This is also shown in the end elevation of the same figure.

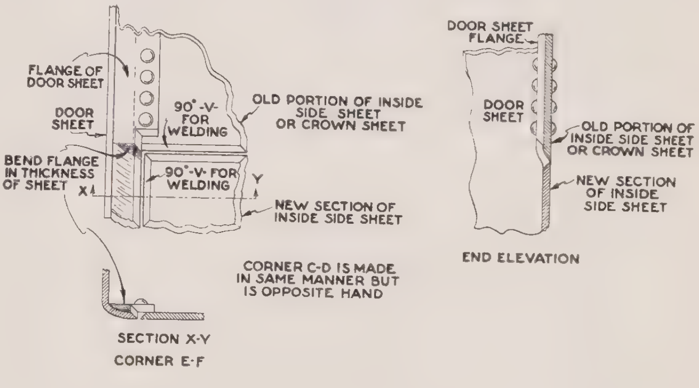

FLANGE OF DOOR SHEET
DOOR SHEET
90° -V- FOR WELDING
OLD PORTION OF INSIDE SIDE SHEET OR CROWN SHEET
BEND FLANGE IN THICKNESS OF SHEET
X
90°-V- FOR WELDING
Y
NEW SECTION OF INSIDE SIDE SHEET
CORNER C-D IS MADE IN SAME MANNER BUT IS OPPOSITE HAND
SECTION X-Y
CORNER E-F
DOOR SHEET FLANGE
DOOR SHEET
OLD PORTION OF INSIDE SIDE SHEET OR CROWN SHEET
NEW SECTION OF INSIDE SIDE SHEET
END ELEVATION

Figure 8—Details Showing the Corner Welds, C-D and E-F, of Figure 6.

A corrugation is formed in the upper part of the sheet directly under the horizontal weld, indicated by the center line of corrugation, shown in Figure 6. This corrugation is formed in the sheet, as shown in detail in Figure 9. The width of the corrugation is a little greater than the corrugation for patches, but the effect is generally similar. The corrugation is not made vertically down the end of the sheet at each end, because this is unnecessary. The seams from No. 1 to No. 17, Figure 6, and from No. 13 to No. 20 of the same figure are welded to the flanges of the door sheet and the flue sheet, respectively, and as these flanges are bent at right angles to the sheet, the bend is sufficient to take care of expansion and contraction. On the other hand, the side sheet is to be rigidly held in place at the mud ring, 17-25, of Figure 6, and the corrugation will assist in offsetting the effect of expansion and contraction as welding continues.

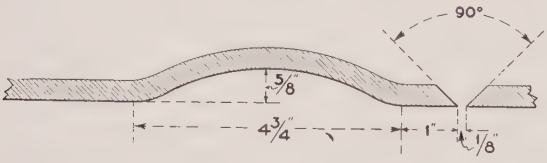


Figure 9—The Corrugation, the Dimensions of Which Are Shown in This Sketch, Is Used for Half Side Sheets and Door Sheet Patches Around the Fire Door Opening. The Corrugation Is a Little Wider Than Shown for Patches in the Inner Side Sheets.

After the side sheet has been cut to fit the opening made in the firebox, allowing one-eighth of an inch between the bevelled edges of the ninety degree vee all around the sheet, the new half sheet is securely bolted in place using a five-eighths inch bolt through every fifth staybolt hole and screwing a staybolt from the outside between each of the five-eighth inch bolts. This practice is, of course, not continued over the whole sheet, but adjacent the corrugation and along the door, flue and throat sheets to securely hold the sheets in place. Drift pins are also driven through the rivet holes in the sheet into the rivet holes in the mud ring. The object is to securely hold the sheet in position and allow the corrugation to take care of the expansion and contraction of the steel.

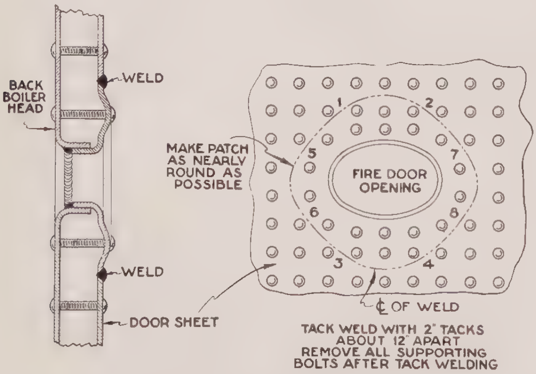

BACK BOILER HEAD
WELD
WELD
DOOR SHEET
MAKE PATCH AS NEARLY ROUND AS POSSIBLE
FIRE DOOR OPENING
1
2
5
7
6
8
3
4
℄ OF WELD
TACK WELD WITH 2" TACKS ABOUT 12" APART
REMOVE ALL SUPPORTING BOLTS AFTER TACK WELDING

Figure 10—Welding a Patch Around the Fire Door Opening. Note the Corrugation Used in This Repair. A Patch Should Preferably Be Made as Nearly Round as Possible.

Some welders recommend tack welding this seam every twelve inches. Assuming that the numerals shown in Figure 6 represent the tack welds, they recommend welding first from No. 2 back to No. 1, then from No. 3 back to No. 2, from No. 4 to No. 3, from No. 5 to No. 4, and so on, using what has already been referred to as the back-step method of welding. In similar manner tack welds would be made at 14, 15, 16, 18, 19, 20, 21, 22, 23 and 24. Welding would then proceed from 14 back to No. 1, from 15 back to No. 14, from 16 to 15 and so on until the seam reaches the mud ring. In like manner welding would take place along the flue sheet and the throat sheet, working from No. 18 to No. 13, No. 19 to No. 18, No. 20 to No. 19 and so on, until finally finishing the weld at No. 25.

Of course, the practice should be followed, that after welding from No. 2 to No. 1, the center line of the corrugation, lying under this section of weld, should be heated to a red heat. When the weld from No. 3 to No. 2 has been completed that section of the corrugation should be heated to a red heat in similar manner, and so on down the weld until the entire horizontal weld has been completed.

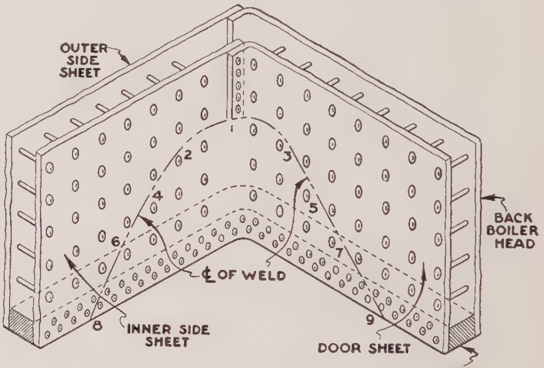


Figure 11—A Corner Mud Ring Patch Where the Weld Is Made in the Inner Side Sheet and the Door Sheet. Note the Particular Shape of This Patch. These Sloping Sides Are Preferable to Vertical Sides Extending Down to the Mud Ring.

Another method of accomplishing this same result is to weld without tack welding. In this event the use of bolts and staybolts must be sufficient to securely hold the sheet in place and the drift pins must hold the sheet to the mud ring, so that it cannot move. All expansion and contraction caused by welding the horizontal seam must be taken care of in the corrugation. No tack welding is done at all, the weld begins at No. 1 and continues for about two inches. The torch is then moved to No. 2 and the weld is made back to No. 1, then to No. 3 and the weld made back to No. 2, then to No. 4 and back to No. 3, and so on using the back-step method until the entire weld across the sheet has been made. Welding then starts at No. 14 and is carried up to No. 1, No. 15 up to No. 14, No. 16 up to No. 15, and so on. The practice is similar at the flue sheet and the throat sheet.

After the weld has been completed, all staybolts are put in place and the sheet riveted to the mud ring. In some instances the staybolts are all put in place before the weld is completed, but if this is done the staybolts must not be driven (riveted over at the ends) until after the weld has been completed and the sheets cooled down.

Sometimes when the mud ring rivets are in good condition and the lower portion of the side sheet is sound, the new section may not extend clear to the bottom of the mud ring, but may be welded to the old portion of the sheet parallel to the mud ring and just above it. In this instance the lower seam is welded first and then the upper seam welded as heretofore described.

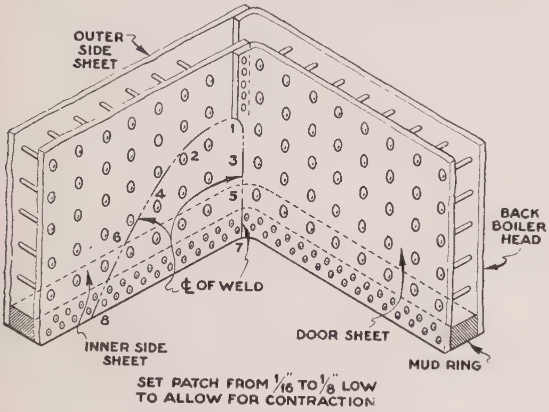


Figure 12—A Corner Mud Ring Patch in the Inner Side Sheet Extending to the Riveted Seam Between the Side Sheet and the Door Sheet.

Still another method of welding these long horizontal seams consists in starting at the center of the seam, as at 7, and welding about two inches, then starting at No. 6 and welding to No. 7, then from No. 8 to No. 7, then from No. 5 to No. 6, from No. 9 to No. 8, from No. 4 to No. 5, from No. 10 to No. 9, from No. 3 to No. 4, from No. 11 to No. 10, No. 2 to No. 3, No. 12 to No. 11, No. 1 to No. 2 and No. 13 to No. 12, alternating from one side to the other of the center. If there is a lower seam it would be welded first in similar manner. This method is also called the back-step method, but welding is started at the center of the horizontal seam instead of from one or the other ends of this seam.

All of these methods of welding take into account the difficulty caused by expansion and contraction of the steel and have been developed to overcome these troubles. Some welders may prefer one method and some another, but whether the routine of welding is one way or the other is not important, providing the welder accomplishes the purpose of making a sound, strong weld without placing unnecessarily "locked-up" stresses in the steel. It will be noted in Figure No. 6 that the horizontal riveted seam between the crown sheet and the side sheet is marked fifteen inches below the top of the crown sheet. The Boiler Laws require that welded seams shall be at least twelve inches below the top of the crown sheet, and it is the practice of some railroads to require that the seam be fifteen inches below the top of the crown sheet, in order that an old seam may be cut out and a new one welded in place which will be within the law, that is, not less than twelve inches below the top of the crown sheet.

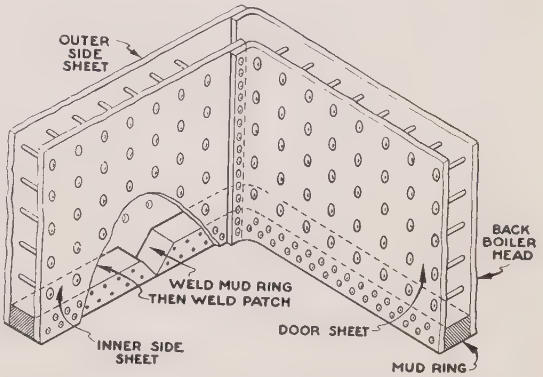


Figure 13—Welding a Break in the Mud Ring. The Inner Side Sheet is Cut Away to Make the Mud Ring Accessible and This Opening Is Subsequently Patched. The Break in the Mud Ring May Be in Another Location, But the Procedure Is Generally the Same.

Welding a Door Hole Patch

A fire-door patch is illustrated in Figure 10. A patch around the fire-door opening in the door sheet should be made as nearly round as possible, forming the patch in such manner that the line of weld will come between the staybolts. This patch should be so formed that it will appear generally as shown in the section of Figure 10, having a corrugation of the dimensions shown in Figure 9 all the way around the fire-door opening. This corrugation will take care of expansion and contraction and the weld in the door collar may be made as illustrated.

The old sheet should be cut out along the line marked "Center line of weld," including at least one row of staybolts within the patch. The edges of this cut should be bevelled and the patch should be carefully fitted into place, after having been

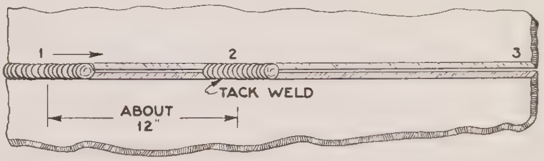


Figure 14—Sketch Illustrating an Excellent Method for Spreading the Far Ends of a Seam if They Crowd Together. Welding Is Stopped at the Point 1, and About Twelve Inches Ahead Along the Seam a Tack Weld, 2, Is Made. Welding Is Begun Again at 1 and Continued Toward 2.

shaped as shown, with its edges bevelled to forty-five degrees, so that the included angle of the vee is ninety degrees, as is common practice. The space between the edges of the ninety degree vee should be one-eighth of an inch as usual, and two inch tack welds should be made, approximately twelve inches apart, all the way around the patch, as indicated by the numerals in Figure 10. For instance, assuming that these figures represent tack welds, there would be eight of them in all in a patch of the size shown. Welding should begin at the tack weld 2, and continued to the tack weld 1. It should then begin at the tack weld 4 and continued to the tack weld 3. The torch should then be moved to 6 and the welding continued upward to 5, then to 8 and continued upward to 7. The next weld should be made between 4 and 8 and then between 5 and 1 and this method should be continued until the patch has been welded all the way around, alternating from side to side, as welding proceeds.

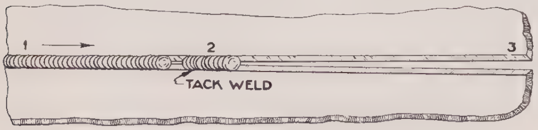


Figure 15—As the Weld Approaches the Tack Weld, 2, the Far End of the Seam, 3, Will Spread.

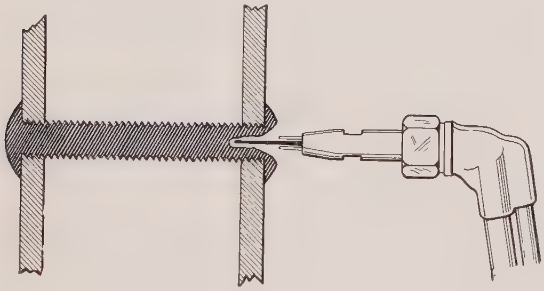


Figure 16—Cutting Staybolts. The Torch Is Held with the Center Line of the Tip in Line with the Center Line of the Staybolt and the Cut Started.

Corner Mud Ring Patch

Patches which are often very convenient, and are not normally counted as patches in a side sheet are similar to the patch shown in Figure 11. This patch extends around the corner in the inner side sheet and in the door sheet. Both of these sheets are cut out with the torch, the line of cut being between the staybolts. It is important that the shape of the patch be generally similar to that shown in Figure 11, and that vertical sides of the patch be avoided. After the old sections of the two sheets have been cut away, the edges are bevelled and a new piece is fitted into place with holes drilled for the staybolts and for the rivets through the mud ring.

A patch of this kind is usually clamped in position with clamps and the patch is set from one-sixteenth to one-eighth of an inch low to allow for contraction when the patch cools, which will draw up the lower edge of the patch to meet the mud ring. Slightly smaller bolts than the mud ring rivets may be used, if desired, and the patch securely bolted to the mud ring. The procedure in welding follows the general rules for welding a break from the inside of the break toward the edge. That is, welding should begin at No. 1 and be continued to No. 2. It should then begin again at No. 1 and be continued to No. 3. The torch should then be moved to No. 2 and welding continued to No. 4; then from No. 3 to No. 5; from No. 4 to No. 6; from No. 5 to No. 7, and so on until the bottom of the seam is reached. Alternating from side to side in this manner will tend to keep the patch in shape and to prevent its tendency to overlap the sheet.

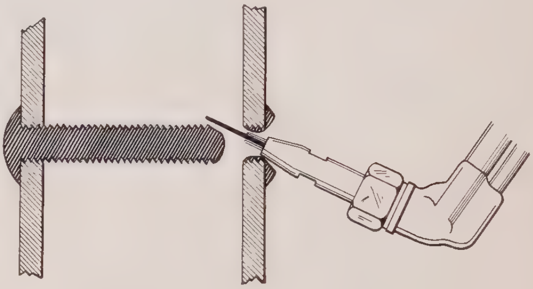


Figure 17—As the Cutting Jet Burns into the Staybolt, the Torch Is Rotated to Cut the Bolt Off on the Inside of the Sheet.

Another method of welding is to make approximately a two inch weld at No. 1; then starting at No. 2 weld toward No. 1. Likewise, start at No. 3 and weld to No. 1, then from No. 4 to No. 2, from No. 5 to No. 3, from No. 6 to No. 4, and so on until the lower edge of the sheet is reached, alternating from side to side of the patch. The object is the same in either case to compensate for expansion and contraction in such manner that the sheets will not be pulled out of shape.

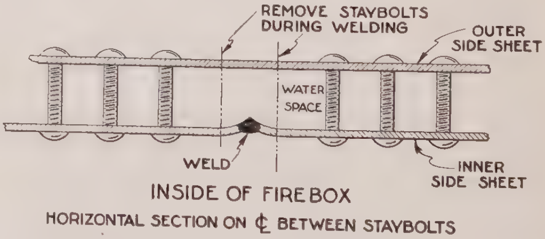

REMOVE STAYBOLTS DURING WELDING
OUTER SIDE SHEET
WATER SPACE
WELD
INNER SIDE SHEET
INSIDE OF FIREBOX
HORIZONTAL SECTION ON ℄ BETWEEN STAYBOLTS

Figure 18—When the Crack Is Not More Than Two Rows of Staybolts in Length, It May Be Welded, as a Temporary Repair Only, by the Method Shown. The Edges of the Sheet Along the Crack Are Driven in Toward the Water Space and Welded. Contraction Pulls the Joint Nearly Flat.

Corner Patch in Inner Side Sheet

In Figure 12 a patch of a little different type is illustrated. This patch instead of extending into the door sheet is made in the inner side sheet and extends only to the edge of the rivet holes of the door sheet flange. This flange is cut out to the edge of the rivet holes in exactly the same manner as described for the half side sheet. The flange is bent over to meet the edge of the patch in the same manner as illustrated in Figure 8.

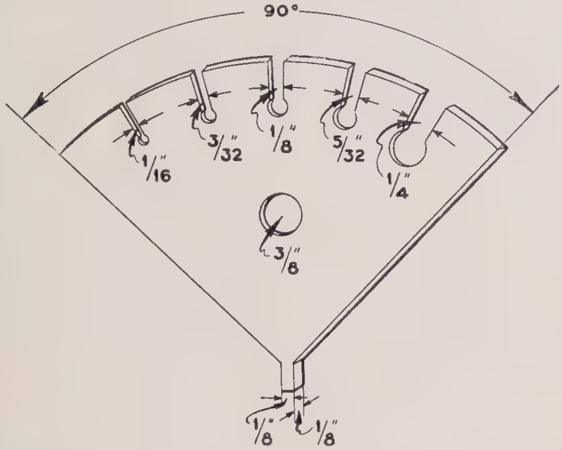


Figure 19—A Useful Templet or Gauge to Check the Angle of the Vee and to Maintain the Correct Distance Between the Sheets. It is Also a Welding Rod Diameter Gauge.

Welding is accomplished by welding for about two inches at No. 1 and completing this corner seam, then welding from No. 1 to No. 2, then from No. 1 to No. 3, then from No. 2 to No. 4, from No. 3 to No. 5, from No. 4 to No. 6, from No. 5 to No. 7 and from No. 6 to No. 8. It will be appreciated that the object in this instance is the same as in the corner patch illustrated in Figure 11. A corner patch of this type is also not counted in considering the total number of patches in a side sheet before renewing the sheet or half sheet.

Welding a Broken Mud Ring

If the mud ring is cracked or broken, it can be repaired as illustrated in Figure 13. This illustration shows a part of the inner side sheet cut away to make the crack in the mud ring accessible. The mud ring is then veed to an included angle of ninety degrees, as shown, and welded in the usual manner, with which the welder is now thoroughly familiar. There are no special problems in the welding of the mud ring, but as it is a heavier section, it will require more time and greater heat. It is often desirable to use a preheating torch upon a section of this size in order to maintain heat necessary to accomplish a good weld. The veed section shown should be built up completely with the sides flush and the top of the mud ring reinforced slightly. Care should be taken, however, not to weld the outer side sheet to the mud ring.

When the weld in the mud ring is completed, the edges of the inner side sheet are bevelled and a patch is cut to fit the opening, as heretofore described for mud ring patches. The patch is welded in the usual manner, beginning at the top of the patch and welding alternately downward on each side towards the edges. The mud ring rivets are then inserted and the job is complete.

Expanding a Seam

An excellent method of expanding a seam which has crowded together beyond the weld is shown in Figures 14 and 15. This method is simple and is known to many welders. It may be used in some instances while in others it may be insufficient for the purpose. It is presumed that the weld is continuing in the direction of the arrow at No. 1, Figure 14, and that the far edges of the seam at No. 3 are found to be crowding close together so that by the time the weld reaches this point they will be crowded hard and one of the edges will attempt to ride over the other.

Under such circumstances the welder should stop welding at No. 1 and move the torch ahead about 12 inches along the seam to a point No. 2 where he should make a tack weld an inch or two long. He should then begin welding again at No. 1 and continue the weld toward No. 2, as shown in Figure 15. As the weld approaches the tack weld No. 2, it will be found that the edges No. 3 will spread apart. This method may be continued a number of times along the seam and may be found extremely useful.

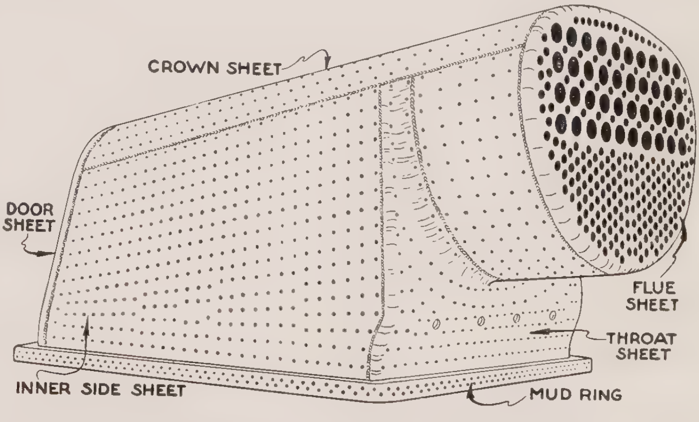


Figure 20—Sketch Showing a Completely Welded Firebox. Note the Mud Ring Forming the Foundation of the Firebox.

Cracks in Firebox Sheets

The welding of cracks in firebox sheets is, as a rule, only a temporary repair. Welded cracks are not to be considered a permanent job, and when so made should be replaced with patches at the earliest opportunity. Cracks in the side sheets of a firebox may be welded as indicated in Figure 18, but under no circumstances should cracks in the crown sheet be welded. In Figure 18 a crack is shown lying between the rows of staybolts. The edges of the crack are driven in toward the water space, and after removing the adjacent staybolts, the weld is made as indicated.

If the crack extends through the staybolt holes, it may be treated in the same manner, but the staybolt holes should be welded solidly, beginning at the bottom hole and continuing the weld upward, welding each staybolt hole as it is reached. The holes are afterwards drilled and tapped, but this work should not be done until the steel is completely cold. The staybolts may then be replaced. The contraction of the sheets tends to straighten out the bends placed in them along the edges of the crack. If a crack is longer than two rows of staybolts a patch should be applied.

Welding Rods

The use of proper welding rods is a very important matter in firebox welding. Nickel steel welding rods, described under No. 5 on page 155, of the American Welding Society Specifications will give good results for firebox welding.

An excellent rod for firebox welding is the No. 1 High Test rod, described under No. 7, page 155. This rod flows easily, does not spark appreciably and produces a very strong weld.

There are other rods upon the market, which are obtainable by the welding shop, but great care should be taken to select a good rod, because upon the strength of the weld metal depends the strength of the job. Opportunities for reinforcing the weld in firebox work are not as great as in many other cases, and the weld metal, therefore, should be as strong as possible.

Chapter No. 3

Hard Alloy Overlays

HARD alloy overlays are being applied to a large number of machines and other parts which are subject to hard service. Agricultural machinery and road machinery offer a very large field for welded overlays. Originally, hard surfacing alloys were used principally to increase the life of drilling bits for oil wells in the oil fields. This use proved so successful that the process has been extended to all kinds of machine parts which are subject to severe wear, as well as to tools, dies, etc., used in general machine shop work. The greatest field at the present time for the welding shop appears to be the hard surfacing of agricultural implements, road machinery, contractors' machinery and equipment and other machines where parts wear away in service and must either be replaced or built up with some hard alloy which renders them again serviceable.

Generally speaking, these alloys are divided into three classes, those having an iron base alloyed with chromium, manganese, silicon and similar metals; those which are non-ferrous, consisting of alloys of chromium, tungsten and cobalt and those of the tungsten-carbide group. These three classifications, of course, are very general and there are many alloys of various metals for hard surfacing purposes upon the market. It is not intended to discuss the relative merits of these hard surfacing alloys, but to acquaint the welder with their use and to give him some idea of which alloy to use in specific instances, particularly in connection with iron base alloys, about which there has been some confusion in the mind of the average man. Furthermore, the methods of application and the points of application of these various alloys have not been clearly understood, and have been under discussion since the use of hard overlays became general.

Application of Non-Ferrous Alloys

The application of Stellite consisting principally of chromium, cobalt and tungsten was very carefully described on pages 148 and 149. On these pages the method was given in detail and it is unnecessary that it should be repeated in this chapter. Other alloys which are not iron base alloys and have a lower melting point than iron or steel should be applied in generally similar manner. This method of applying the non-ferrous alloys is a process of brazing. The part upon which the overlay is to be applied is preheated if possible and the surface brought up to a sweating heat with the torch. The flame is then adjusted until it has a slight excess of acetylene and the overlay rod melted and flowed over the surface.

The iron base rod, on the other hand, has a melting point which closely approaches that of the iron or steel to which it is being applied and these rods should, therefore, be welded to the surface of the part. In this instance, the part is preheated if possible, but the surface of the steel is actually fused and the overlay rod is welded to this fused surface just as any other welding rod is applied. There is this distinct difference between the two types of rod and it is repeated here in case the student has not clearly understood this fact during his study of Lesson 10.

Iron Base Rods

Stoodite is a hard alloy, iron base welding rod made in four sizes, three-sixteenths inch in diameter by eight inches in length; and one-quarter inch, five-sixteenths inch, and three-eighths inch in diameter, by ten inches in length. Instead of being a fabricated rod, similar to the construction of Borod and Stoody rod (illustrated in Figure 1), it is a solid cast alloy rod. It is furnished flux coated for electric welding and bare for welding with the oxy-acetylene torch. While flux is not essential to the use of Stoodite with the torch, it is helpful in many instances.

The melting point of Stoodite is approximately that of high carbon steel and it expands when heated in practically the same amount. Therefore, it can be welded to steel without much more difficulty than is usually encountered in using an ordinary steel rod. It is possible to build up a layer of Stoodite over the surface of any iron or steel part, and this layer is often called an overlay. Such an overlay is very hard and tough and will withstand a tremendous amount of abrasion.

The basic element of Stoodite is iron, and this accounts, to a great extent, for its similar characteristics. It is a hard alloy produced in the electric furnace which retains its natural hardness even when red hot. In manufacturing Stoodite the molten alloy from the electric furnace is cast into chill molds to produce the rods. There are certain elements in the alloy a portion of which are burned up during the process of welding, and for this reason more of these elements are added to the alloy, than would normally be necessary, to offset the loss during the welding process.

There is a definite relation between hardness and brittleness of a welded-on overlay, which must be taken into consideration. As hardness of a metal increases, it usually follows that the metal becomes more brittle. If the base, to which the overlay is welded, is solid and heavy, and will take a large part of the strain, the overlay may be harder and more brittle and yet be serviceable. But if the overlay itself must take a considerable portion of the strain, brittleness must be given careful consideration, and an overlay having greater strength and less brittleness might be more serviceable. Such an overlay, of course, would not be as hard, but at the same time would stand up under severe service because it would not break or chip away from the base metal.

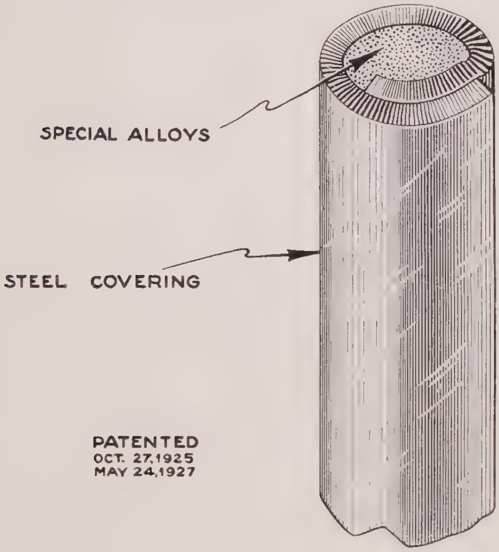


Figure 1—Sketch Showing the Fabricated Construction of Stoody Rod and Borod. A Sheet of Soft Steel is Rolled in the Form of a Tube Surrounding the Metals which Make the Deposit Hard and Tough.

The Stoodite deposit has great wear resistance, and is very hard but is, to some extent, brittle. For this reason, unless well supported, Stoodite should not be used where the part is subject to very hard blows. The deposit is close grained and will resist abrasion to a tremendous extent. Where the wear is very great, but the blows are less severe, Stoodite should be used. Stoodite has another quality which is valuable and that is the fact that these wear resistant characteristics do not decrease with an increase in temperature and Stoodite can be used when heated to a temperature at which tool steel would lose many of its wear resisting or cutting qualities.

Welded-on overlays have the advantage that the surface can be renewed from time to time, as the overlay wears away. This can usually be done without great delay to the machine, and without much dismantling. For this reason, it is often better practice to use an overlay which is stronger, less brittle and, therefore, less hard than it would be to use the extremely hard overlay, which is at the same time brittle and likely to shatter in service. It is not always wise to attempt to gain the maximum hardness in an overlay, if such hardness must be gained by reducing the strength of the part to too great an extent.

Measuring the Hardness of Metals

Hardness of metals is determined by machines which force hardened steel balls or points under measured loads into the surface of the metal. The Rockwell and the Brinnell machines are of this type. The Scleroscope drops a diamond pointed hammer upon a surface and measures the rebound. The Rockwell tester applies a light load to the point and then a heavy load and the additional distance which the point is driven into the metal is the figure which determines the hardness of the metal being tested.

The relative hardness of the overlays produced by various iron base rods is given in the accompanying table. The hardness of the Borod overlay is between sixty-five and seventy on the "C" scale of a Rockwell testing machine.

Relative Hardness of Overlays Made From Various Hard Surfacing Rods

(Comparisons of the three scales are approximate)

Kind of Rod	Rockwell "C" Scale 120° Cone-150 Kilogram Load	Scleroscope Hardness Average of Model "C" and "D"	Brinnell Hardness
Stoodite Deposit	60	80	578
Stoody Self-Hardening Deposit	54	71	495
Silfram Deposit	45	57	375
Stoody Manganese Rod Deposit	30	39	255
Stoody High-Carbon Steel Deposit	15	26	179
Stellite No. 1	54	71	495
Stellite No. 12	48	63	415
Stellite No. 6	40	50	331

Stoody Self-Hardening Rods

The deposit from Stoody Self-Hardening welding rods has considerable structural strength and will, therefore, withstand pounding and shock. While it is hard, it is also less brittle. For this reason it should be used upon parts which will be subjected to considerable pounding and yet at the same time must resist abrasion and wear to a large extent. Of course, the stronger the steel base under the overlay the better, whether the overlay is Stoody Self-Hardening Rod or Stoodite.

Stoody Self-Hardening rod is made in three sizes, one-eighth, three-sixteenths and one-fourth of an inch in diameter and twenty-eight inches in length. It may be applied with either the torch or the electric arc. It is a patented, fabricated rod, being made of a soft steel sheet, or covering, rolled into the form of a tube containing the special hardening alloys within the tube.

These alloys make the deposit from this rod self-hardening and tough. The deposit is not machinable and will not check or break down under continual pounding. It is not brittle and can be forged while hot after welding. It can be welded to and will amalgamate thoroughly with mild and high carbon steels and manganese steel. The deposit hardens in the air as it cools. Figure 1 illustrates the construction of this rod showing the soft steel shell rolled to resemble a tube and the core of other metals used for hardening and toughening the deposit.

In oxy-acetylene welding it has been apprehended that the puddling of the overlay rod with the base steel might dilute the overlay to such an extent that its hardness and efficiency would be materially decreased. There is no doubt that a certain amount of dilution does occur, but provision has been made by the manufacturers of overlay rods to include additional quantities of the hardening elements to counteract any dilution which might occur and the burning away of these elements during the welding operation. Stoody Self-Hardening rods, like all iron base rods, should be thoroughly welded to the surface of the part they are intended to protect, but the depth of this deposit will depend entirely upon the individual piece and the service demanded of it.

There is a certain technique required in the handling of the torch and either Stoody Self-Hardening rods or Stoodite. First grind all scale from the surface to be overlaid. A clean surface is essential. A slightly carbonizing flame should be used, that is, one having a slight excess of acetylene. If the flame is held too long upon either of these metals, they become difficult to handle and scale and slag collect, which prevent the building on of the overlay uniformly and smoothly. After a welder has practiced a little in using either Stoody rod or Stoodite, he will find a very good method of applying it as follows. There are, of course, other methods of accomplishing the same work, just as there are in ordinary welding, but using the principles set forth, the welder can develop his own technique.

The torch may be held in the right hand with the tip and the flame pointing vertically over the surface of the part to be overlaid. Preheating may be accomplished previously in a furnace, or forge, if desired, or it may be done with the torch as the work progresses. If the part to be overlaid is the edge of a blade, for instance, the left hand end of the part may be heated up to a red heat for several inches. The flame may then be concentrated on the extreme left hand surface at the end of the blade, and the surface fused. The overlay rod may then be melted and flowed over this surface.

The torch should not be held any longer than absolutely necessary over the rod and molten overlay, but should be moved away from this zone for a moment and utilized to preheat the area immediately forward and next to be overlaid. It should then be brought back into contact with the overlay rod and quickly moved away again, then back to the overlay rod and forward to preheat. The rod may be rolled on its end over the surface and back.

In this manner the flame is used to heat and melt the surface immediately forward of the overlay rod and is brought back to the overlay rod only enough to keep it fused and flowing over the surface as the process is carried along the edge. If care is taken to prevent the flame from being held in contact with the overlay metal too long, it will be found to flow much better and to produce a smoother overlay than can be otherwise accomplished.

The overlay applied in this manner may progress in any direction and cover any desired area, the torch always preceding the overlay to heat the metal as the overlay advances.

Flux may or may not be used as the operator prefers. If the method described is used it is not essential.

All overlay metals may be applied in this manner if desired, but it will be found that some of them flow or run over the surface to be covered much better than others.

Silfram

Silfram is a cast alloy welding rod, containing, among other metals, some nickel and possessing some of the characteristics of nickel steel. It is an iron base alloy and its deposit is not brittle. The deposit is not only ductile and malleable, but is hard and tough.

It may be welded to any ferrous metal, and provides a hard wear resistant overlay which will not chip or break away from the parent metal. It is supplied in three sizes, three-sixteenths inch in diameter by fourteen inches in length; and one-quarter inch and five-sixteenths inch in diameter by fourteen inches in length. It will be noted from the table of hardness of overlays that the deposit from a Silfram rod is a medium grade of hardness. It is welded to the base metal in the same manner as any other welding rod, but when the torch is used, it should be adjusted for a slight excess of acetylene. For electric welding Silfram is furnished with a nitro-cellulose coating, but for oxy-acetylene welding it is uncoated. Silfram may be used with or without flux. If flux is desired, an excellent flux for the purpose is of a grade similar to No. 1 A-Mal-Gam.

Silfram flows very well upon the parent metal and is, in fact, one of the easiest overlay rods to apply. It flows to some extent like cast iron and alloys or amalgamates thoroughly with the metal part to which it is being applied. Preheating is always good practice in welding overlays to all large pieces because in this event both the overlay and the parent metal cool and contract simultaneously. Silfram, however, has enough ductility so that if it is applied to a piece of cold steel, it will not check or crack as the overlay cools.

High Carbon Rods

High carbon welding rods are furnished in twenty-eight inch lengths, one-eighth, five-thirty-seconds, three-sixteenths and one-quarter inches in diameter. They contain approximately 0.55 to 0.65 per cent of carbon and from 0.97 to 1.15 per cent of manganese. The phosphorus, sulphur and silicon contents of these rods are low. High carbon rods are used for building up worn parts where the part is badly worn away and it is desired to build up the part first to nearly its original contour before applying an overlay. The high carbon rod is less expensive than the overlay rod and the completed repair in this manner will be less expensive to make. The deposits from high carbon steel rods, of course, are stronger and harder than those from ordinary rods.

Increasing the Life of Plow Shares

Hard alloy overlays can be applied to plow shares to produce a hard facing or armour, along the cutting edge and at the point, to prevent wear and thus increase the length of time during which a plow share will give efficient service. The location of this hard alloy overlay, whether upon the top of the plow share, or the bottom, and whether on the top or the bottom of the point is a matter which has been discussed by welders and the men who use plow shares ever since hard surfacing was developed. There is at present much controversy over the location of the overlay, some experienced welders declaring that it should be placed upon the top of the share and others believing that it does better work upon the bottom of the share.

As a matter of fact, it appears that the location of the overlay is dependent, to a large extent, upon the nature of the soil in which plowing is to be done and the service which is demanded of the share. There are almost as many different kinds of soil which must be plowed as there are different localities in the country. It is obvious that a soil which is composed largely of gravel, sand and clay, with many large stones, will not wear a plow in the same manner as a soil which is black loam, or a sandy loam. Where the soil is heavy gumbo or adobe, or is matted with roots, it is essential that the edge of the plow be sharp, but there are localities where the nature of the soil is such that the sharpness of the plow is not an important matter.

Therefore, the welder who is surfacing plow shares in a certain district cannot be expected to apply the overlay in exactly the same manner as a welder located in some other district where the soil conditions are entirely different. It will, therefore, be necessary for the welder to determine for himself the condition of the soil in his locality and the location of the overlay to either maintain a sharp edge, protect the edge to best advantage, or to facilitate the scouring of the plow if the soil is a sticky gumbo or other soil in which scouring does not readily take place. For instance, some welders claim that when the hard overlay is placed upon the top of the plow share only, as shown in Figure 2, that the scouring or the self-cleaning of the top of the plow share is difficult in certain soils; also that the steel immediately above the overlay along the edges, marked "C-D," will wear away leaving a valley which makes scouring even more difficult. On the other hand, some experienced men believe that when the overlay is applied to the bottom of the share only, as shown in Figure 5, that the steel above the overlay will wear away, leaving the overlay itself exposed to the thrust of the soil as it is forced over the share and that in some cases the overlay will become broken out, particularly if it is of the very hard, brittle type and the edge of the plow share will become nicked and dented. It will be appreciated that these different opinions are the result of local conditions and that no general rule can be laid down which will fit all parts of the country, or the varied requirements of those who plow the land.

On account of the fact that no standardized practices have yet been developed in this field, each method of applying the overlay will be described and illustrated and the condition involved will be discussed. One of the difficulties which has been complained of in all hard surfacing has been that welders do not take enough pains to thoroughly clean the surface of the share by grinding before applying hard surfacing metal. Furthermore, in many instances, this metal is applied too thick with the result that the edge and point are blunt and dull. There is just as much skill required of the welder in welding a hard alloy overlay to a plow share as in doing any other kind of welding and the subject must be given the same careful consideration.

Before proceeding further with this discussion, it may be well to again remind the student, although this fact was clearly set forth in Lesson No. 10, that there are a number of hard surfacing metals upon the market which require different treatment and care must be taken to consult the directions of the manufacturer of the particular type of hard surfacing metal in use, to be sure that the correct method of procedure is used for the hard surfacing metal at hand.

In general, however, there are, as heretofore stated, among others, three principal types of hard surfacing metals; those which have an iron base, similar to the products of the Stoody Company of Whittier, Calif.; those which are made of non-ferrous alloys, consisting of chromium, cobalt, tungsten and other similar hard metals; and the carbides of some of these metals. One of the non-ferrous alloys is Stellite, made by the Haynes-Stellite Company of Kokomo, Indiana. The welder must recognize that methods of applying these alloys differ, in that the non-ferrous alloys are applied to the plow share by heating the base metal to a sweating heat, but not actually melting its surface as in welding. This is a form of brazing which is generally utilized in applying the non-ferrous alloys. The iron-base alloys, on the other hand, similar to Stoodite, Stoody rod, Silfram, etc., are applied to the base metal as in actual welding. The melting points of these alloys are so close to the melting point of steel that the base metal and the hard alloy overlay are actually welded together by fusing or melting the base metal as well as the alloy.

With these facts in mind, and the previous experience which the welder has had in this course of instruction, he will be able to apply any hard surfacing alloy without difficulty, the principal requirement being that the alloy be placed in the right location upon the part to either self-sharpen the part, or to protect its surface from wear as conditions may require.

Method A

This method of applying a hard alloy overlay to plow shares is illustrated in Figures 2 and 3. The overlay is placed along the cutting edge of the top of the share, one-half inch wide and one-sixteenth of an inch in thickness. At the point of the share, the overlay extends two inches from the point and is one-eighth of an inch in thickness. On the bottom of the share, as shown in Figure 3, the overlay is placed two inches from the point of the share and it is omitted along the bottom of the cutting edge and along the surface A. It is claimed that in many soils this method of placing the overlay is very satisfactory. The steel of the share is protected by the overlay on the top of the cutting edge and the overlay is thin enough to avoid bluntness of this edge. The top and the bottom of the point are also protected by the overlay, but the surface A will wear to keep the point sharp.

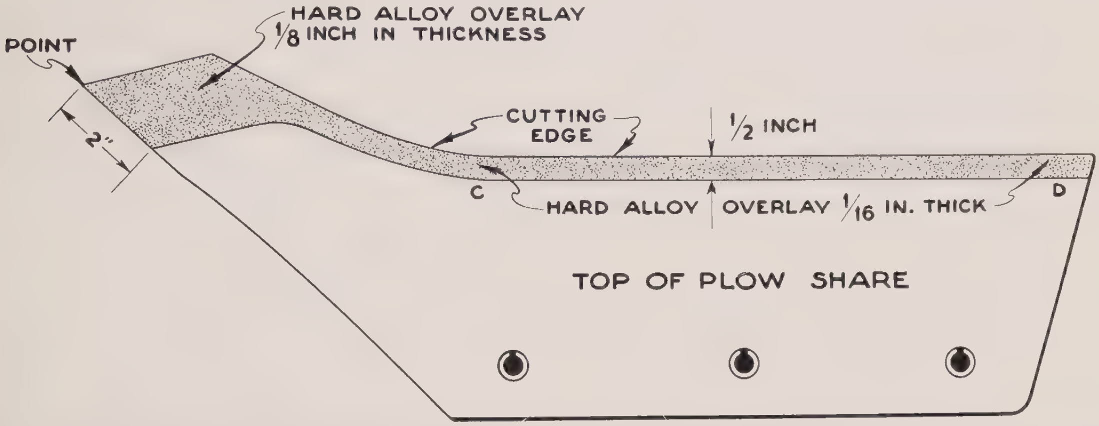

HARD ALLOY OVERLAY 1/8 INCH IN THICKNESS
POINT
2"
CUTTING EDGE
1/2 INCH
C
HARD ALLOY OVERLAY 1/16 IN. THICK
D
TOP OF PLOW SHARE

Figure 2—The Hard Alloy Overlay, in this instance, is Placed on Top of the Plow Share Along the Cutting Edge and at the Point. The Overlay is not Placed Along the Cutting Edge on the Bottom of the Share, but only at the Point, as shown in Figure 3.

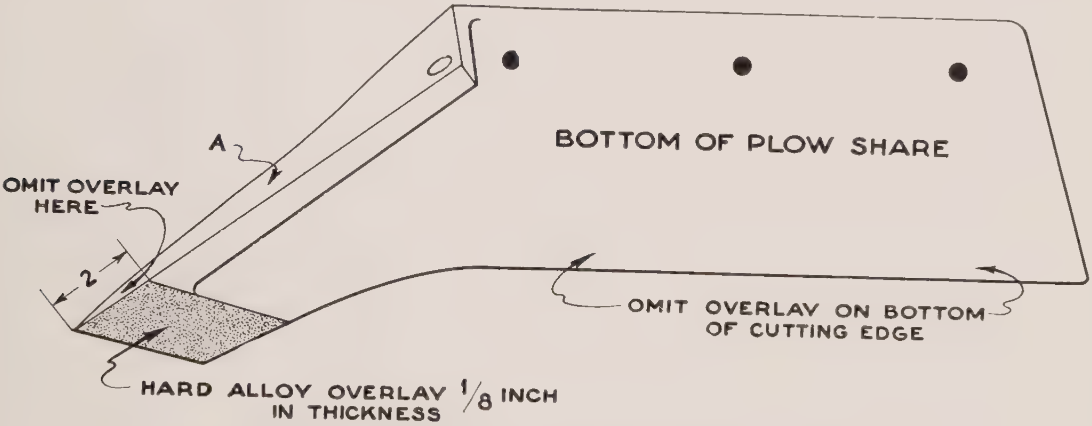

A
OMIT OVERLAY HERE
2"
BOTTOM OF PLOW SHARE
OMIT OVERLAY ON BOTTOM OF CUTTING EDGE
HARD ALLOY OVERLAY 1/8 INCH IN THICKNESS

Figure 3—This is a View of the Bottom of the Plow Share, shown in Figure 2. The Hard Overlay is Placed at the Point only and not Along the Bottom of the Cutting Edge.

While this method may serve to good advantage in some soils, it is claimed that in others the plow does not properly scour, that is, the soil as it passes over the top of the share does not keep the top of the share polished and clean, on account of the interference of the overlay with the normal action of the soil. Some welders also claim that in certain soils the steel above the overlay will gradually wear down, causing the valley, heretofore mentioned, immediately above the overlay on top of the share. It is likely that the thickness of the overlay has a good deal to do with both these conditions. If the overlay is too thick, there must be a ridge of hard surface metal immediately above the cutting edge which would account, to some extent, for the wear described.

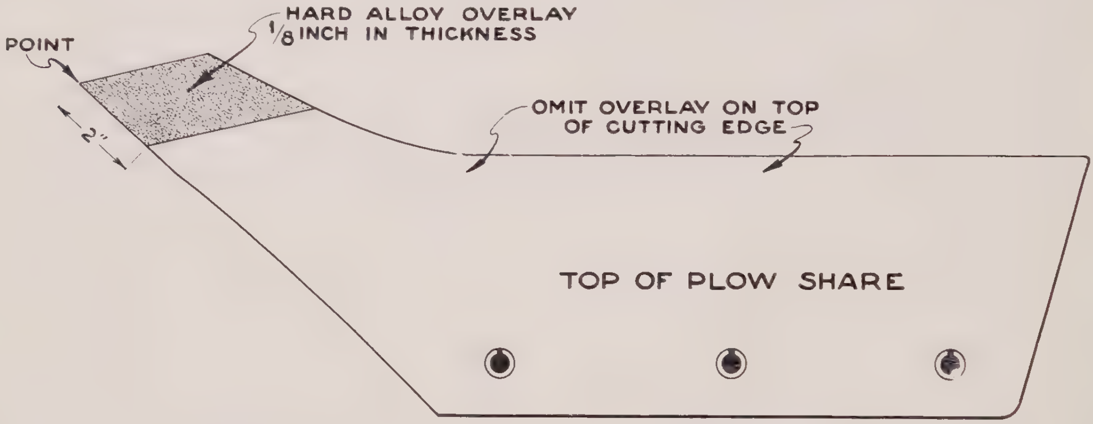


Figure 4—The Second Method Described in the Text is Illustrated in Figures 4 and 5. The Hard Alloy Overlay is Placed at the Point only, on Top of the Plow Share.

This method was declared to be the most satisfactory in hard plowing land in a section of Illinois near Rockford. The soil consisted largely of a clay base, with sand and gravel and a considerable number of boulders. The hard alloy overlay was Stellite, and the test indicated that the action of the soil wore away the steel at the bottom of the cutting edge and maintained a sharp edge. The shares were rough ground on the top edge to smooth up the hard alloy as much as possible, but were not finished in any other way. It was stated that the scouring action started immediately and was satisfactory. Furthermore, the point was self-sharpening, because of the lack of the overlay on the surface A, Figure 3. While this test proved to the satisfaction of those who conducted it that, in this type of soil, the method gave excellent results, others have claimed that this method will not suffice at all in soils occurring in other localities in the same state. For this reason, Method B is described and illustrated herewith.

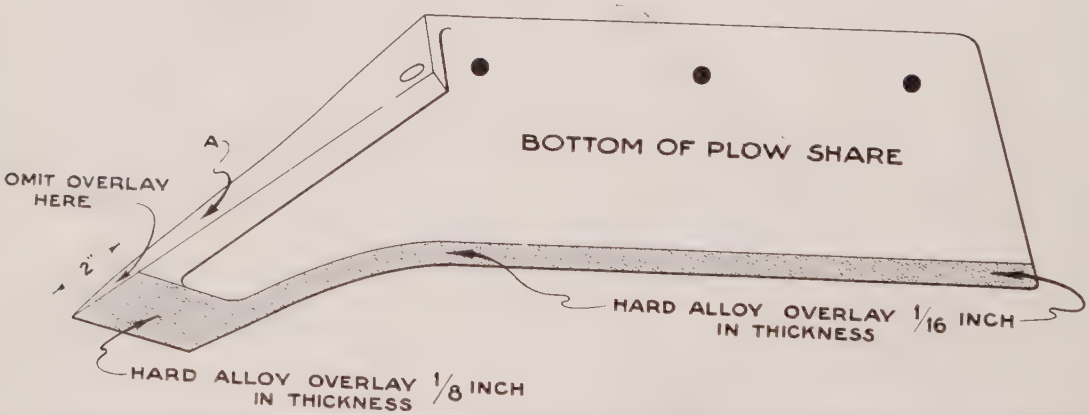


Figure 5—In this instance, the Hard Alloy Overlay is Placed on the Bottom of the Plow Share at the Point, and along the Cutting Edge, as shown in this Figure, and at the Point only on Top of the Plow Share, as shown in Figure 4.

Method B

This method is illustrated in Figures 4 and 5. It consists in placing the hard alloy overlay, one-sixteenth of an inch in thickness, along the cutting edge on the bottom of the plow share, as shown in Figure 5, and for two inches on the underside of the point, one-eighth of an inch in thickness. The top surface of the point for a distance of two inches is also overlaid one-eighth of an inch in thickness. There is no overlay, however, on top of the cutting edge, nor is there any overlay on the surface A.

A variation of this method is illustrated in

Figure 10 where the overlay is placed in similar manner on the bottom of the plow share, but no overlay is placed on the top of the point, as illustrated in Figure 4. Whether or not, the overlay is placed on the top of the point in this method seems to be a matter of preference. In some soils it may serve to protect the point to a greater extent, but it must have the disadvantage that the point will not have the same self-sharpening features which it would if the overlay were placed only on the bottom. Of course, the point itself, where marked point, would remain sharp, because the surface A is not overlaid and this would wear to a certain extent.

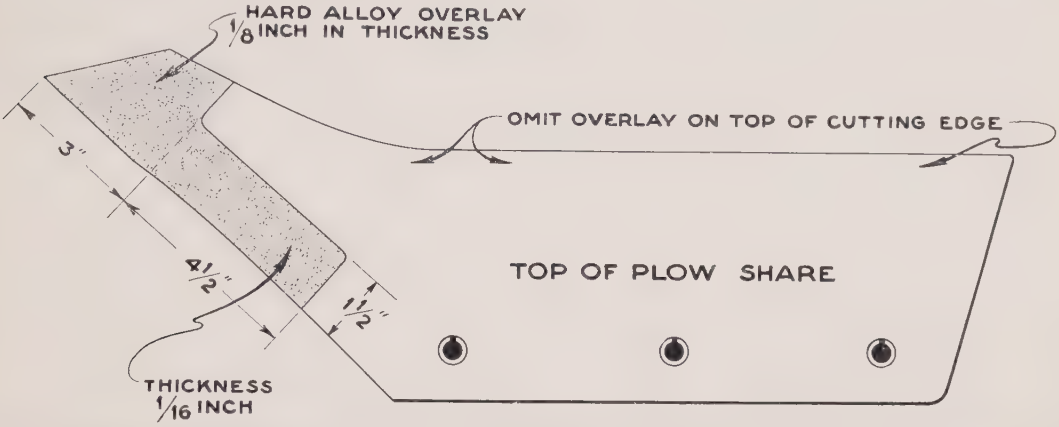

HARD ALLOY OVERLAY
1/8 INCH IN THICKNESS
OMIT OVERLAY ON TOP OF CUTTING EDGE
3"
4½"
1½"
TOP OF PLOW SHARE
THICKNESS
1/16 INCH

Figure 6—The Method of Applying the Overlay, shown in Figures 6 and 7, is the Result of Experience Where the Wear on the Bottom of the Plow Share is Prevented by the Extent of the Overlay, and Considerably More of the Overlay is Placed on Top of the Share. Figure 7 Shows the Overlay as Applied to the Bottom.

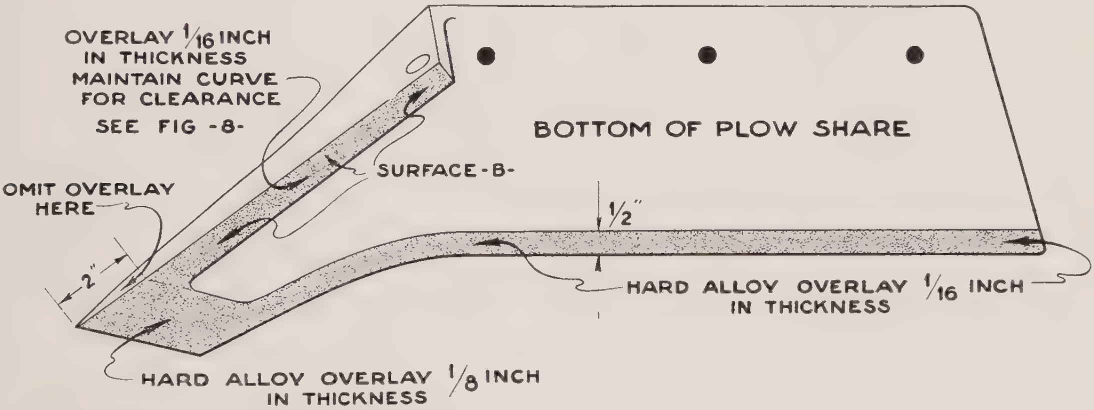

OVERLAY 1/16 INCH
IN THICKNESS
MAINTAIN CURVE
FOR CLEARANCE
SEE FIG -8-
BOTTOM OF PLOW SHARE
SURFACE -B-
OMIT OVERLAY
HERE
½"
2"
HARD ALLOY OVERLAY 1/16 INCH
IN THICKNESS
HARD ALLOY OVERLAY 1/8 INCH
IN THICKNESS

Figure 7—In this instance, the Welder Placed the Overlay along the Surface B, as well as at the Point and Along the Cutting Edge of the Bottom of the Plow Share. It should be remembered that the Clearance Curve along the Surface B must be Maintained. This Curve is Illustrated in Figure 8.

When the overlay is placed on the bottom of the cutting edge, as illustrated in these figures, the top of the share must scour, because no hard surfacing metal has been applied to it, and the surface condition remains unchanged. Furthermore, the wear of the soil as it passes over this upper surface will continually wear down the softer steel and maintain a sharp cutting edge. It has been argued, however, by welders who have applied the hard overlay in this manner that the steel along the cutting edge will wear completely away from the overlay metal, exposing it to the thrust pressure of the soil. They claim that the unsupported overlay if it consists of a very hard brittle alloy will chip when stones or boulders are struck and the edge will soon become broken and ragged and will collect debris, roots, etc.

This would seem to be an extreme condition and might occur in certain soils, whereas in others the abrasive action would not be severe enough to produce this result.

An example of a share, hard surfaced in this manner, was demonstrated in the southern part of Illinois not long ago where 280 acres were plowed after the hard alloy overlay had been applied as described on the under side of the share with a small band of overlay along the top of the point. The soil was hard and dry, but when the job was done there was not sufficient wear of the edge or point of the share to be detected by ordinary means of measurement. The top edge of the point of the share was touched up with a grinding wheel and the share was ready again for service.

Method C

Still another method is illustrated in Figure 6 and 7. This consists in placing the overlay, one-half inch in width and one-sixteenth of an inch in thickness over the cutting edge on the bottom of the plow share, as illustrated in Figure 7, and of the same thickness on the surface B, also for a distance of two inches from the point, one-eighth of an inch in thickness. The top of the share along the cutting edge is not overlaid, but the overlay, one-eighth of an inch in thickness, is placed for a distance of about three inches over the point and extends backwards one-sixteenth of an inch in thickness for four and one-half inches, about one and one-half inches wide, as illustrated in Figure 6.

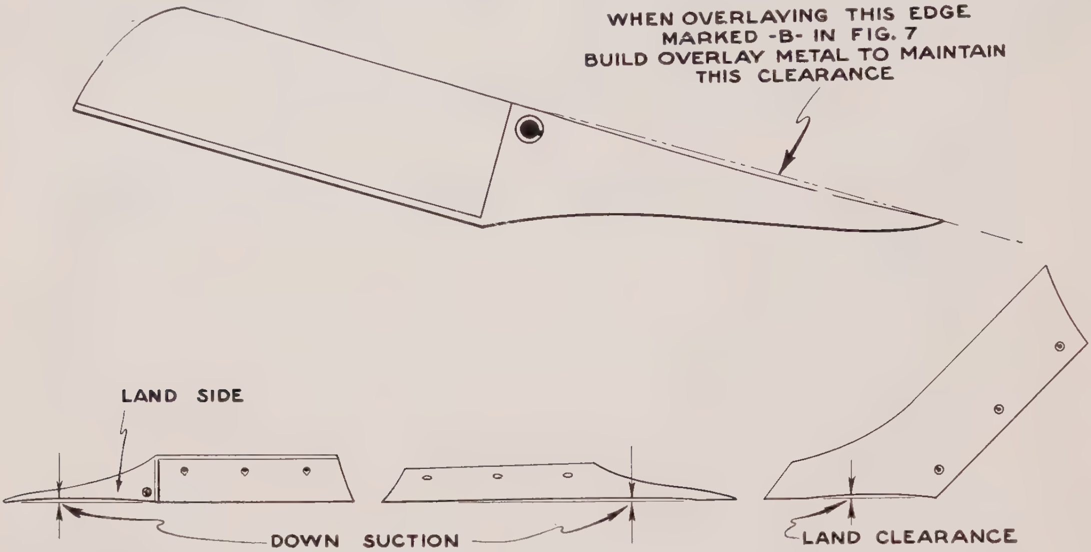


Figure 8—The Welder Should Secure a New Plow Share and Measure the Down Suction and the Land Clearance. These Curves Must be Carefully Maintained When Repointing or Overlaying Plow Shares. Knowledge of the Amount of Clearance Which Should be Allowed Will Help Him to Repair Plow Shares so that They Will Work Properly.

This is a method which has been advocated by a man with a long experience in farming, who afterwards became a skilled welder. In the type of soil, to which he was accustomed, the abrasive wear at the point of the share was such that the steel wore away and he found that protection was necessary. For this reason, he applied the hard overlay to the top of the share, as shown in Figure 6. Furthermore, on the bottom of the share the surface B wore away to a considerable extent and he overlaid this surface, taking care to maintain the clearance illustrated in Figure 8. The welder must not forget that the surfaces of a plow share are designed to curve with definite objects in view, and he must not alter these curved surfaces any more than he can help, or he will alter the action of the plow so that it will not function as originally intended.

A variation of the practice described in method A is shown in Figure 9. This consists in placing the overlay entirely on top of the share and omitting it from the bottom of the share, even at the point. The advantages and disadvantages of this method would be the same as in method A, with the exception that the steel at the point would wear away at the bottom, causing the point to be self-sharpening, which might not be the case in method A where the overlay is applied to both the top and the bottom of the point.

Still another method has recently been described by Fusion Facts, a publication of the Stoody Company. This method was tried out in the Northwest and consisted in applying Stoody Self-Hardening rod along the cutting edge on the bottom surface of the share from the rear end of the cutting edge, marked H in Figure 10, to within about two inches of the point. The overlay was fairly heavy and when it was completed, the share was placed in a blacksmith's fire, heated and then forged until the cutting edge was of the right thickness and sharp. Stoody Self-Hardening rod has the unusual characteristic that it can be forged after welding. By drawing the edge in this way, after the overlay has been applied, the thickness of this part of the share may be as much or as little as is required in the opinion of the welder.

The point was then squared up and shaped to its proper contour, and after the scale had been removed from the top and the bottom of the point, Stoodite was applied as far as it was thought necessary to both the top and the bottom surfaces of the point. Furthermore, a short overlay of Stoodite was placed for about three-quarters of an inch along the rear end of the cutting edge, marked H. It will be noted that in this instance no forging was done after Stoodite had been applied, because this metal is harder than the Stoody rod and cannot be forged in the same manner. This method, of course, involves more work than those described heretofore, but if it satisfies the user and the plow stays sharp for a longer period of time in the soil of the locality, it is worth the additional effort and the time required on the part of the welder.

What Grade of Overlay Should be Used for Plow Shares?

The Haynes-Stellite Company recommends the No. 1 grade of Stellite for plow shares where the hardest grade is required and the edge is not subjected to too much shock. The various grades of Stellite were fully described on page 149 of Lesson No. 10. If there is any doubt in the mind of the welder as to which grade of Stellite should be used, he should consult the manufacturer who will designate for him the correct grade for use in the soil in his locality.

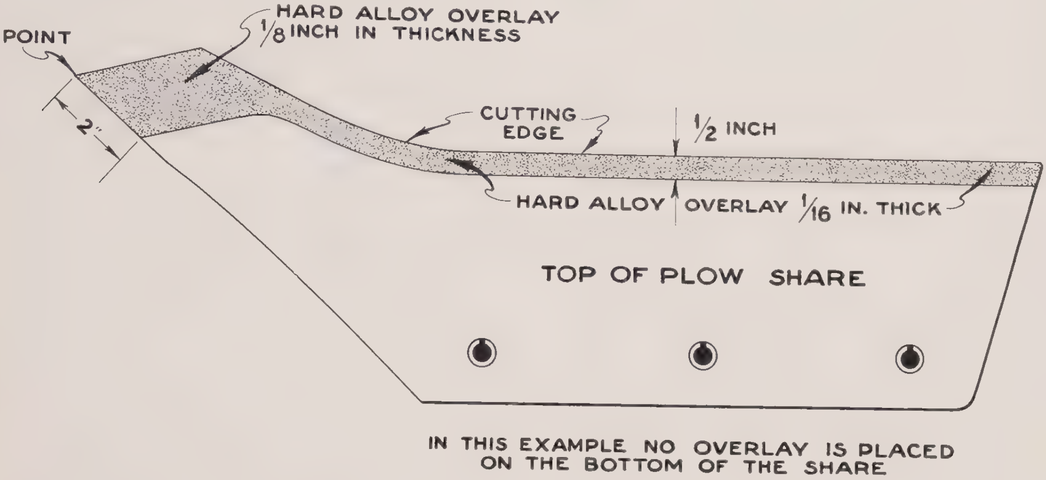

HARD ALLOY OVERLAY 1/8 INCH IN THICKNESS
POINT
2"
CUTTING EDGE
1/2 INCH
HARD ALLOY OVERLAY 1/16 IN. THICK
TOP OF PLOW SHARE
IN THIS EXAMPLE NO OVERLAY IS PLACED ON THE BOTTOM OF THE SHARE

Figure 9—This Figure shows still Another Method Where the Overlay is Placed only on the Top of the Plow Share, None being Placed on the Bottom.

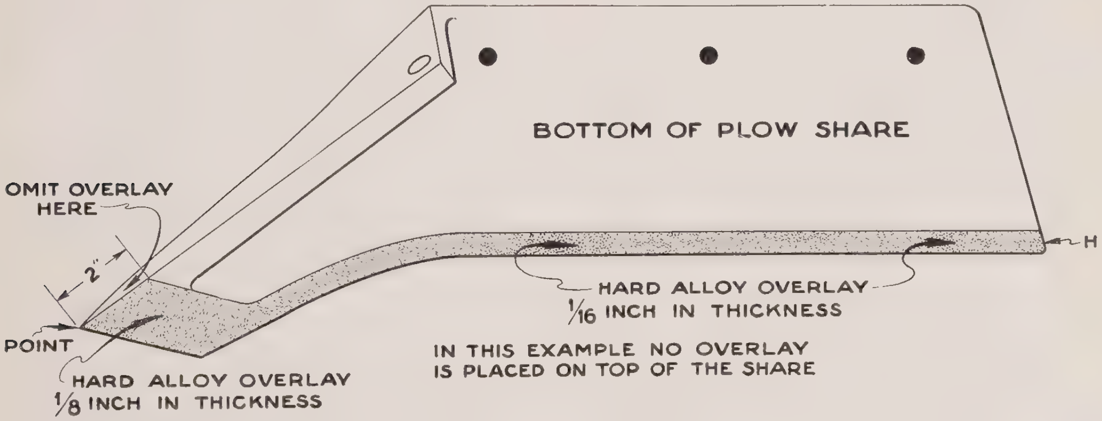

BOTTOM OF PLOW SHARE
OMIT OVERLAY HERE
2"
POINT
HARD ALLOY OVERLAY 1/8 INCH IN THICKNESS
HARD ALLOY OVERLAY 1/16 INCH IN THICKNESS
H
IN THIS EXAMPLE NO OVERLAY IS PLACED ON TOP OF THE SHARE

Figure 10—A Method is shown where all of the Overlay is Placed on the Bottom of the Plow Share and None on the Top.

The Stoody Company, on the other hand, particularly recommends Silfram for use upon plow shares. Silfram is not as hard as Stoodite, but will stand more pounding and is tough. Furthermore, it flows easily upon the surface of the share and amalgamates or combines well with the base steel. Silfram is, therefore, particularly useful where the soil is tough and rocky. On the other hand, where the abrasion of a sandy soil cuts and wears away the overlay, it is found at times that Stoodite, which is the hardest of the three, or Stoody Self-Hardening rod, which comes next in the scale of hardness, may be more satisfactory. The overlay from any one of these rods may be ground after it is applied if necessary, but if the welder is skillful, grinding will not ordinarily be required upon agricultural implements.

There are, of course, other hard surfacing alloys upon the market, beside the three mentioned upon page 148. In the event of their use, the directions of the manufacturer should be consulted and if full information is not available welders should write to the manufacturer to determine the most satisfactory manner in which they may be applied.

Importance of Hard Surfacing Plow Shares

The owner of a welding shop or a blacksmith shop equipped with welding apparatus will find the building up of plow shares and other agricultural implements with hard alloy overlays to be a very profitable portion of his business if he will take the trouble to develop it. All of the cutting edges and many surfaces of agricultural implements are exposed to extreme wear. The life of these parts can be extended as much as five times in certain instances by the application of hard overlays.

The cost of such overlays is well within reason, and the user of the agricultural machinery saves considerable money each season. Furthermore, the welding shop owner profits and will continue to do so if he puts forth the effort to fully develop this comparatively new method of armoring the surfaces of parts subjected to wear.

Hardening Plow Shares

There are a number of different types of plow shares in common use in the United States, among these being shares made of laminated layers of steel, usually called soft center plow shares. The two outside layers are of a higher carbon steel, which is hard, while the center layer is made of low carbon or soft steel. The thickness of the plow share is generally divided into thirds, although in some instances the outside layers are not as thick as the center layer. These three layers of steel are welded together and make shares which have a hard outer layer, or skin, and a tough, strong interior which will not usually break. Soft center plow shares are used to a very large extent in many parts of the country. There is another type of share also used to a considerable extent, and these are known as crucible shares. They may be made of crucible steel, and, in some instances, are made of open-hearth steel. These shares are, however, not laminated and are of carbon steel which will harden.

Another type of share, used to a large extent in Indiana and other districts where the soil is sandy, is the chilled iron share, made of cast iron chilled in a chill mould. These shares are quite cheap and, usually, when they are worn out are thrown away. Of course, the cast iron is very hard and resists abrasion to a high degree. As a rule, no attempt is made to overlay chilled iron shares. Overlaying is applied principally to the crucible and the soft center shares.

There is a condition which prevails, however, even on a soft center share which must be taken into consideration. When the point of the share is well worn away, it pays to weld a new point to the share, rather than to attempt to build up the old point with welding rods. This is fully described on page 137. The old, worn point is cut off and a new point is welded in place.

Points made of cast steel have been sold to a considerable extent. These points, however, have been largely replaced with forged steel points, made of steel higher in carbon and more suitable for the purpose, which produce much better points of the shares than the cast steel points previously used. When a point of this kind is welded to a soft center plow share, the point is, of course, of the same grade of steel throughout. In similar manner when this point is welded to an open-hearth, or a crucible steel share, the same condition prevails. The new point is unhardened after it has been overlaid.

After an overlay has been welded to the edge and the point of the share, there is a portion of the surface, immediately adjacent the overlay, which has been heated to a red heat and slowly cooled. This surface must of necessity be softer than the remainder of the surface of the share and will wear to a greater extent than the surface which has been hardened and not heated. It is a practice of some welders to cool the plow share in air after a hard overlay has been applied. Quenching will not increase the hardness of the overlay, because this hardness is due to the metal from which the overlay is made and not to any subsequent heat treatment. The normal practice of a blacksmith in hardening a soft center share is to heat the entire share to a red heat, sprinkle it with potassium or sodium cyanide, or prussiate of potash and quench the share in water.

This is a form of quick carburizing and case hardening. The prussiate of potash, or the cyanide, whichever may be used, cleans and adds to the surface of the steel additional carbon which combines with the steel in such manner that it can be made hard by quenching in brine, water or oil. The addition of the carbon to the steel is called case carburizing, and the hardening of this surface, by quenching in water, is called case-hardening.

Some plow shares which the welder may encounter are made of crucible or open-hearth steel. The exact carbon content of these shares he, of course, will not know. The carbon content of steel has a very direct bearing upon its hardening characteristics. For instance, a steel containing 0.20 per cent of carbon can be hardened with difficulty and only by heating it to a temperature which is at least 1,500 degrees Fahrenheit. Heating steel to this temperature is objectionable, and unnecessary if the carbon content is slightly higher. A steel containing 0.25 per cent of carbon can be hardened by heating it to a lower temperature than 1,500 degrees, but at least to a cherry or full red, as shown in Figure 5, Chart No. 6, page No. 109. When the steel is thus heated, it is quenched in water or oil.

Quenching a plow share made of crucible or open-hearth steel of sufficient carbon content to harden places tremendous locked up strains in the steel, which may, if these strains are too great, cause the steel to break or fly apart. The steel is also very hard and very brittle. In the case of a share, if it struck a solid piece of rock or a boulder, it would probably crack or break, even if it had not broken previously. The common practice to lessen the brittleness and hardness of steel, after it has been quenched from a red heat, is to reheat the piece to varying temperatures, depending upon what the steel is to be used for, and again quenching it. This is called drawing the temper, and is commonly known to all blacksmiths and to those who are familiar with the working of steel. The welder, however, does not always possess a good knowledge of tempering and he should study this subject until he is thoroughly familiar with it.

By heating a share under such conditions, to a temperature of about 600 degrees Fahrenheit, or approximately a blue heat, the hardness and the brittleness of the steel are let down or decreased, so that it is not as hard as it was originally and many of the strains within the steel have been adjusted. It is not believed that the welder should ever attempt to heat a crucible or an open-hearth plow share in its entirety and plunge it into water to harden it after he has repointed such a share or has overlaid it with a hard overlay metal. This treatment is too drastic and is not necessary. He can harden the point of the share without difficulty by quenching the point only, or by partly quenching the steel adjacent to the overlay where it has been heated to a red heat. The blacksmith will know how to harden a plow share, but if the welder is not familiar with practice of this kind, he must give the matter very careful consideration in his treatment of the share after he has overlaid it as described in this chapter.

It is easy enough in the case of the soft center share to harden those portions of the share, which it is believed have been annealed, by heating the share to a cherry red, sprinkling cyanide, or potash, over the surface and quenching the share in water. There will be no difficulty in this treatment of these shares and the overlay will not be injured or affected in any manner. Of course, the practice will vary with different blacksmiths and in different sections of the country.

Thresher Teeth

Figure 11 illustrates a thresher tooth. These teeth are set in a cylinder which revolves at a high speed. The teeth pass between other rows of stationary teeth set in the frame with a limited amount of clearance. The straw as it passes through the thresher is thus broken into short lengths and the teeth are subjected to severe pounding and wear.

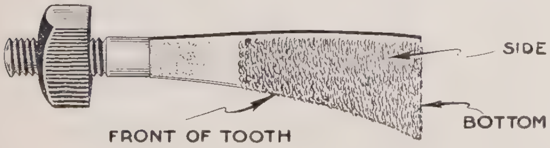


Figure 11—Sketch Showing a Tooth of a Threshing Machine. These Teeth are Subject to Hard Pounding and Severe Service.

Either new or old teeth may be overlaid, and on account of the severity of the service, Silfram is recommended by the Stoody Company for this purpose. The front, bottom and sides of the tooth, indicated in Figure 11, should be ground to brightness and slightly smaller than size. An overlay of about one-eighth inch of Silfram should be welded to these surfaces of the tooth. Of course, old worn teeth may require considerably more overlay than one-eighth of an inch in thickness. In fact, an old tooth may be worn to such an extent that the original contour is unknown to the welder. In this event, he should procure a new tooth from the manufacturer of the threshing machine and use this new tooth as a pattern to produce the necessary templet so that he can build up the old tooth to its correct contour.

This can easily be done by taking a piece of sheet brass and laying the new tooth upon it after the nut has been removed. The outline of the tooth can then be scribed on the brass and the brass within this line cut away to make an opening through the brass sheet the exact shape of the tooth when it lies on its flat side. The tooth should then be laid on the brass sheet on edge and its outline again scribed to produce an opening in the brass templet, which is the shape of the tooth in its narrow dimension.

In this manner the welder will have an exact guide by which he may determine the shape of the tooth both ways. He should then build up the contour of the tooth with Silfram until he has it as nearly, as he can judge, the exact size and shape of the new tooth. If he finds that he has built up too much metal upon any surface, it can be ground down until the tooth will just slip through the templet.

It is very important that the shape and the size of these teeth be maintained as exactly as possible, because the clearance between the revolving teeth and the stationary teeth is not great, furthermore, if they are built up too heavy they may upset the balance of the revolving cylinder. If they were much too large, they might strike the stationary teeth and completely wreck the machine. Any other hard surfacing metal of the correct degree of hardness and toughness may be used for building up these teeth.

Repointing Shovel Teeth

Steam shovel teeth become badly worn after relatively short use. Figure 12 illustrates such a tooth, which has been worn down until it is about three inches shorter than it was originally. Restoration of such teeth was accomplished as follows:

A piece of soft steel plate was cut of sufficient length to build out the tooth to its original length and of the width of the tooth. This soft steel plate was welded to the tip of the worn tooth, as shown in Figure 13, great care being taken to heat the manganese steel as little as possible. A low carbon steel welding rod was used for the purpose. The low carbon steel welding rod was used to partially restore the contour of the tooth, as shown in Figure 14. High carbon steel rod was then selected and this was welded to the soft steel plate and the original tooth until the contour was built out to resemble Figure 15. Finally an overlay of Stoodite was welded to the surface of the built-up portion and the original tooth until the contour of the tooth was built up to that shown in Figure 16.

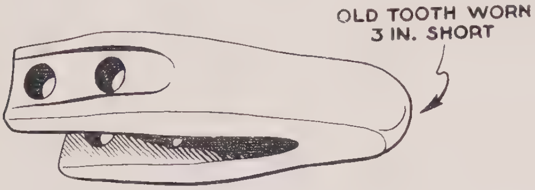


Figure 12—An Old Worn Steam-Shovel Tooth which is Three Inches Shorter than It was When New.

This was, of course, an expensive method for repointing a tooth, and it would have been much cheaper to hard surface or overlay the digging end of the tooth with Stoodite when the tooth was new, and to maintain this surface as the tooth wore down.

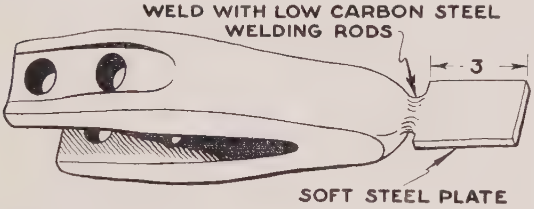


Figure 13—To Repoint this Tooth, the First Step is to Secure a Piece of Soft Steel Plate and Weld it to the End of the Tooth as Shown.

The welder will, however, encounter many steam shovel teeth that are worn down as illustrated in Figure 12, and in this event, it is excellent practice to rebuild them as described. After they have been treated in this manner, as they wear down they can be built up again with a new overlay and thus maintained in good serviceable condition.

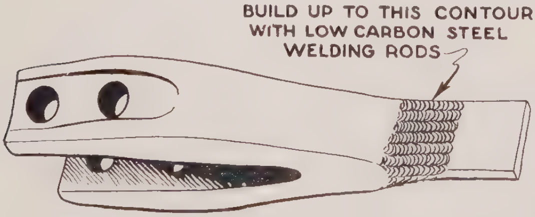


Figure 14—Complete the Weld Between the Plate and the Tooth, Using Low Carbon Steel Welding Rods. Make this Weld Sound and Solid.

Whether Stoodite or Stoody rods, should be used for the final overlay will depend entirely upon the service to which the teeth are to be put. If the shovel is digging in a bed of sand or clay, where the rock or boulder formation is not heavy, or difficult, Stoodite should be used because this metal will withstand the abrasion and cutting of sand and gravel. On the other hand, if the shovel is in use in shoveling a heavy rock formation, where the pounding of the teeth against the rock is exceedingly severe, Stoody rod will be found more satisfactory than Stoodite, and in such instances, Silfram may also be used, because Silfram produces an overlay which is both tough and strong.

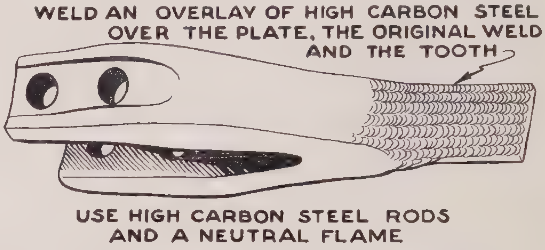

WELD AN OVERLAY OF HIGH CARBON STEEL
OVER THE PLATE, THE ORIGINAL WELD
AND THE TOOTH
USE HIGH CARBON STEEL RODS
AND A NEUTRAL FLAME

Figure 15—Continue the Building Up Process by Welding an Overlay of High Carbon Steel Over the Plate and the Tooth.

Manganese steel dipper teeth in the Hawaiian Islands lasted about three days while digging through rock. The dipper teeth were upon a steam shovel. The manganese steel teeth were overlayed with Stoody rod with the result that the teeth lasted fifteen days, or more, during the digging of this rock formation.

Borod

Borod, manufactured by the Stoody Company, is a fabricated rod made in the form of a tube of soft steel enclosing a composite of mixed alloys which are principally tungsten carbide. This composite is firmly held in the steel casing, as illustrated in Figure 1. The rod is covered with a thin coating of flux and the whole coated with a nitro-cellulose compound to protect both flux and rod from moisture.

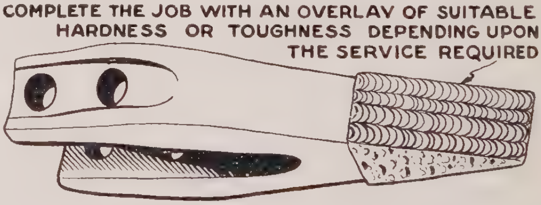

COMPLETE THE JOB WITH AN OVERLAY OF SUITABLE
HARDNESS OR TOUGHNESS DEPENDING UPON
THE SERVICE REQUIRED

Figure 16—Stoodite or Stoody Rod may be Finally Used to Overlay the Entire Wearing Surface of the Tooth. Stoody Rod is Recommended when the Shovel is Working in a Hard Rock Formation. Stoodite May be Used when the Material is Sand, Gravel or Clay with less Rock.

Tungsten is a metal which occurs almost exclusively in rock containing granite. Tungsten ore is found usually near the shores of the Pacific ocean. Southeastern Asia produces the largest quantity of this ore and the United States and Mexico rank second and third in production. Tungsten ore is also mined in South America, principally in Bolivia. In the United States it is mined in California and Colorado.

Tungsten is a very hard steel gray metal, which melts at a temperature of about 6,150 degrees Fahrenheit. Its heat conductivity is slightly less than aluminum. Its tensile strength when drawn into wire is 500,000 pounds and it is very heavy, weighing 0.678 pounds per cubic inch. It is very hard even after being heated to a red heat and it is used to a large extent in manufacturing high speed steel for machine cutting tools. It has the highest melting point of all metals. The strength of tungsten increases with working or drawing. The ingot has a strength of only about 18,000 pounds and a swedged rod about 50,000 pounds. When the metal is drawn into very fine wire, the strength increases until a wire having a diameter of one-half mill has the strength of about 700,000 pounds per square inch.

High speed steel contains about eighteen per cent of tungsten. When the metal is very finely divided, it is black in color, but if coarser the color becomes gray. Ingots are prepared by pressing the finely divided black powder in molds and heating the metal to near the melting point. It is afterwards swaged and worked until it finally becomes ductile. It is added to steel largely as ferro-tungsten, which is a combination of iron and tungsten, containing about seventy per cent tungsten.

Tungsten-carbide is formed by exposing tungsten heated to high temperatures to carbon monoxide, or to hydro-carbon gases. The tungsten and the carbon combine to form a very hard alloy, known as tungsten carbide.

When Borod is used as a welding rod, to weld or deposit an overlay over a piece of steel, the soft steel sheet melts readily and the fine particles of tungsten carbide mix with it. Some of the particles mix with the steel and others are embeded in the molten mass to form a hard, tungsten, iron, carbon alloy.

The rod is used like any other rod, the molten alloy being fused to the surface of the steel to form a hard, armored layer over the softer steel underneath. The process is actual welding, not brazing, and the surface of the steel must be well melted before the Borod is applied. There should be as little puddling of the Borod or mixing it with the steel of the part being welded as possible, because such puddling dilutes the alloy and makes the overlay less hard than it is in the purer state. The torch is adjusted to a neutral or slightly carbonizing flame and, while a flux is not necessary, it may be used if desired.

Borium

Borium, also manufactured by the Stoody Company, is fused tungsten carbide marketed in broken pieces and classified according to size and shape. On account of the very high melting point of tungsten carbide, neither the oxy-acetylene flame nor the electric arc will melt it. It is applied to well drilling tools in suitable sizes by being imbedded in the overlay, usually of Stoodite, over the exposed surfaces of the bit or tool. Thus Borium is substituted for industrial diamonds, heretofore set in the bit and used only for extremely hard formation where the performance of a bit studded with diamonds warranted the expense. Borium pieces are not as hard as diamonds, but range in hardness between the sapphire and the diamond and are so much less expensive than diamonds that the use of Borium has become economical where the cost of diamonds would be prohibitive.

Aside from Borod and Tube Borium, this grade of tungsten carbide is made in two distinct forms each of which serves a separate purpose. The two forms of standard or hard Borium are Pea Borium Inserts and Standard Shape Borium Inserts. Pea Borium Inserts are made in four sizes, one-quarter by three-sixteenths inches, five-sixteenths by one-quarter inches, three-eighths by five-sixteenths inches, and seven-sixteenths by three-eighths inches. Standard Shape Borium Inserts are made in rectangular and half oval shapes from one-half to one inch long and of various dimensions.

Borium is also furnished in granulated sizes, encased in a tube. This is called tube Borium and the tubes range in diameters from one-eighth to three-eighths inches and fourteen inches in length, according to specific requirements. The granulated Borium within the tube may range from coarse pieces of a screen size of five to eight, to the very fine granulated Borium of a thirty to forty screen size. These may be classified to specific sizes, or there may be a mixture of the various sizes, depending entirely upon the requirements of the user.

About 0.407 pounds of acetylene Tube Borium rods are required to deposit one cubic inch of metal. About 6.5 cubic feet of oxygen and 6.9 cubic feet of acetylene are required to deposit one cubic inch of Tube Borium. For oil well drilling tools, the pea Borium in various sizes is used to a large extent. For grader blades and scarifier teeth, the tube Borium may be used of the ten-twenty size, or the twenty-thirty size, as may be desired. Either pea Borium or tube Borium may be obtained flux coated and may be used to good advantage with the oxy-acetylene torch, although flux coated Borium is not essential for use with the torch. The uncoated Borium can be used with the torch very successfully.

Road Grader Blades

Road grader blades have been overlayed with tube Borium with a great resultant saving in the life of the blade. In one case in California a Borium overlayed blade was used upon sixty miles of road and still retained its cutting edge, although it had not been touched since it was placed upon the grader. If the ordinary type of steel blade had been used upon this job, it was stated that four blades would have been required to do the same work which was accomplished with one blade after the edge had been overlayed with tube Borium. Of course, Stellite, Stoodite or Stoody Rod may any one of them be used for overlaying road grader blades, and there are a number of other hard surfacing metals which can be similarly used for this purpose. The use of Borium, however, is probably less familiar to welders, and will be described in detail.

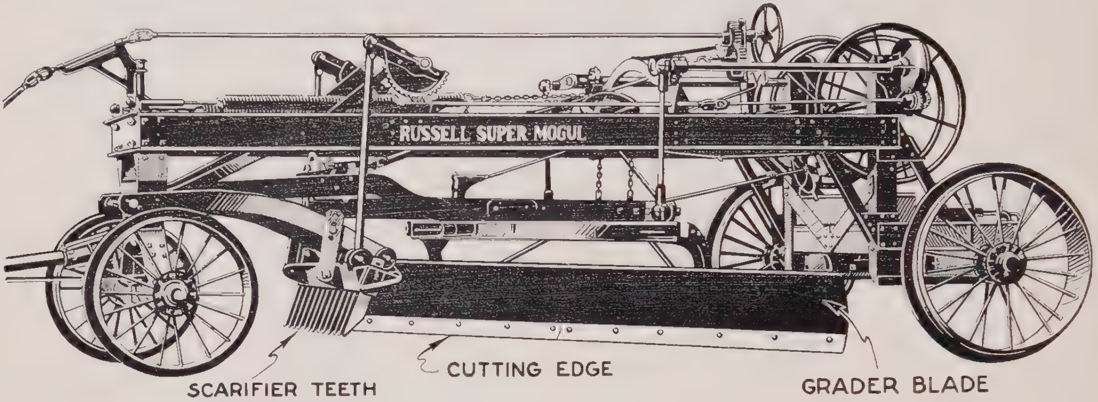


Figure 17—Sketch of a Combined Road Grader and Scarifier. The Grader Blade and the Scarifier Teeth are Clearly Indicated. The Wear Upon the Edges of Road Grader Blades and the Points of Scarifier Teeth, Which Have Been Hard Surfaced, Depends Largely Upon the Angles at Which They are Operated. Some Engineers Recommend Tilting Blades and Teeth to Angles of 40 or 45 Degrees With the Horizontal, Pointing in the Direction of Motion.

Figure 17 shows an illustration of a road grader together with the blade and the scarifier teeth, both clearly marked so that there will be no confusion as to what these parts are. In use both are subjected to very severe service and will not wear, when made even of the best steel, for any great length of time. Until the use of hard overlays was put into practice, these teeth and blades were replaced and sharpened frequently and the cost of replacements and re-sharpening was a very considerable item. The application of an overlay of hard surfacing alloys will be discussed first as applied to road grader blades and secondly to scarifier teeth.

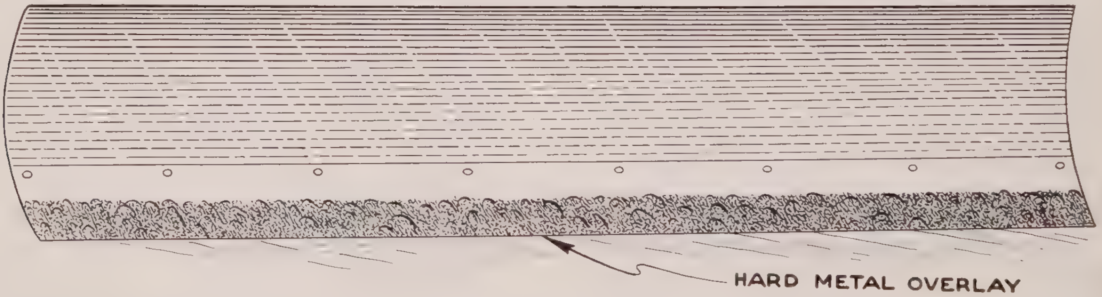


Figure 18—Sketch Showing a Road Grader Blade with the Cutting Edge Bolted to the Blade. An Overlay of Hard Surfacing Metal is Shown on the Forward Side of the Cutting Edge.

It will be noted in Figure 17 that the cutting edge of the grader blade is bolted to the blade as shown. The cutting edge is made from special steel and, for the longer blades, is in two sections. Some of the cutting edges are three-eighths of an inch in thickness, some as light as five-sixteenths inches, and the heavier cutting edges are one-half inch. The width of a three-eighths inch cutting edge is about six inches. If tube Borium is used, the ten-twenty or twenty-thirty sizes are usually selected for road equipment. The ten-twenty size has been used for overlaying road grader and maintainer blades and has given very satisfactory results.

The tube Borium is fused with the torch over the molten surface of the cutting edge, three and one-half to four inches above the cutting edge itself. The overlay is placed on the front side of the blade, as indicated in Figure 18. It must be overlaid about one-eighth of an inch in thickness.

The steel cutting edge is quite long and not very heavy and will warp unless it is bolted securely to a stiff steel member of some kind. It can be bolted through the bolt holes and the size and shape of the stiffener or beam to which it is bolted will depend upon the availability of such a part. It might be a heavy I-beam or a channel, or a piece of bar steel long enough to back up the entire length of the cutting edge. A cutting edge, bolted to an I-beam for overlaying with Borium, is shown in Figure 19.

Before welding any overlay to steel parts of this kind, it is always desirable to preheat the part and this is essential in connection with an overlay of Borium. A small part, of course, which can be readily handled, can be preheated in a common forge or with charcoal in a temporary firebrick furnace built for the purpose. A road grader blade, bolted to the supporting beam, is, however, too long to handle in a fire of this kind and it has been the practice to use the torch to preheat ahead of the actual welding of the Borium overlay to the cutting edge. The size of the tip will depend, to a large extent, upon the thickness of the cutting edge, the kind of a bar which is used for a backing and the amount of heat which it will conduct away from the blade. A fairly large tip is usually necessary and the steel of the cutting edge should be preheated for several inches ahead of the weld. The Borium tube is used just like any other welding rod and the surface of the steel melted before the tube Borium is fused over it. As stated heretofore, the particles of Borium will not melt because the heat of the oxy-acetylene torch is not sufficient to melt tungsten carbide. The steel casing of the tube Borium, however, will melt over the molten surface of the edge and will form a matrix or casting of hard, tough steel surrounding the particles of Borium. These hard particles will be diffused and imbedded over the entire surface of the hard overlay.

When a short section of the blade is coated with the overlay of Borium about one-eighth of an inch in thickness, the torch should be used to preheat the blade ahead of the overlay and to actually fuse its surface before more of the tube Borium is flowed over it. The width of the overlay will depend somewhat upon the blade and the character of the surface, but it should be high enough so that the steel above the overlay will not wear down into a valley. This process is continued along the blade until, from the cutting edge upward for perhaps three and one-half inches, it is uniformly coated with Borium for its entire length. The cutting edge is then removed from the backing bar and bolted to the grader blade itself. No grinding or finishing is attempted and the edge may be rough and jagged. This is not poor workmanship but a characteristic of the use of Borium. As the overlay is placed on the front of the blade where it is subjected to the greatest wear, the softer steel behind the overlay will gradually wear away, producing a continually sharp edge. The blade therefore becomes self-sharpening.

The application of tube Borium, in this manner, to a road grader blade is like any other job of welding. The blade itself must be thoroughly cleaned by grinding the surface before the Borium is applied and there must be a real union between the overlay and the steel of the blade. It should be remembered that while Borium is tungsten carbide, the matrix is steel and therefore tube Borium should be used like other iron base rods and the surface of the steel brought to a fusion heat before the borium tube is melted over it. This will insure a weld just like any other weld and the overlay and the blade will thus become one piece, although of metal having distinctly different characteristics. No overlay is placed on the back of the blade. If this were done, the blade would not have the self-sharpening characteristics just explained and would be dull and blunt.

The welder must use good judgment in the application of Tube Borium. It produces the intensely hard surface characteristics of tungsten carbide, but is expensive and should not be applied indiscriminately without taking into consideration its relatively high cost. While some contractors, recognizing the saving gained by the use of a wide Borium overlay on a road grader blade, are willing to pay the increased cost of such an overlay, others, under different construction conditions, may feel that the excessive hardness of the Borium overlay over three and one-half or four inches of the width of the blade may not be necessary.

Under such circumstances the welder can apply an overlay of Borium for about one inch in width and extending the entire length of the road grader cutting edge. Above this Borium an overlay of less expensive metal may be applied for two and one-half or three inches. A combination which might be advantageous would be one inch of Borium and three inches of Stoody Self-Hardening rod. The road grader edge would then be well protected and the surface of the steel imme-

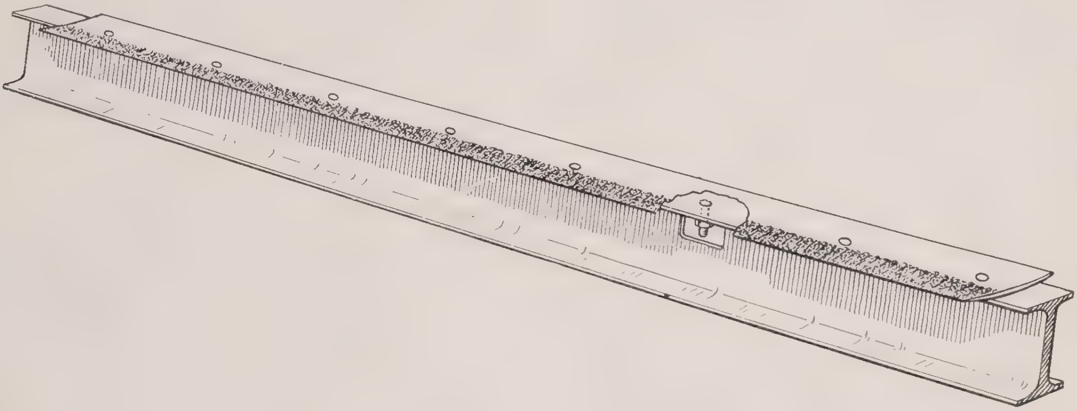


Figure 19—The Cutting Edge of a Road Grader Blade is Shown in this Sketch, Bolted to an Eight Inch I-Beam.

diately above the Borium sufficiently well protected with Stoody Self-Hardening rod. The wear at the edge is, of course, considerably greater than it is above on the surface where the earth and rocks slide upward as the blade is drawn along the road.

The cutting edges of road grader blades may be overlaid with any other good overlay metal, as well as with Borium. The choice of an overlay metal, depends entirely upon the service which is expected from the cutting edge. Stoody rods; Stoodite; Silfram; Stellite; Weldite No. 500 welding rods, manufactured by the Chicago Steel and Wire Co. of Chicago; Flintweld rods, manufactured by the Steel Sales Corporation of Chicago, and many others may be used for the hard surfacing of grader blades. The service expected of the blade, the cost of the overlay, and its hardness and abrasion resistance, must all be taken into account in making the selection.

There is another condition which must be given consideration in certain soils. There are soils consisting of clay and heavy earth which require that the grader blade be sharp and also that it scour well. This is often particularly important when the grader is used for finished grading rather than rough preliminary grading during construction work. If the blade is to be used for finishing work where accuracy is important and sharpness and scouring must also be taken into consideration, the overlay must be so applied that these conditions will result.

The overlay should be put on thin and smooth, great care being taken not to warp the blade so that its cutting edge is not straight. In order to do this, heat must be applied to the opposite edge of the blade to counteract the warping effect of the heat applied to only one edge; otherwise it will not be straight.

It may be necessary to overlay the edge of the blade, allowing it to warp and depend upon straightening the blade after the job is completed. In this event, it may be best to heat the blade in a long charcoal fire, or with preheating torches, and while hot, clamp it to a straight surface. The details of this process, of course, will depend entirely upon the equipment which is available, but usually there must be some means for straightening blades after they have been overlaid.

Silfram flows well and can be applied to a blade for a finishing grader quite thin and very smooth. Another method is to weld Stoody self-hardening rod to the blade and forge the overlay smooth and sharp as the work progresses. This method is similar to that described for the overlaying of plow shares with this rod and forging to make the plow shares sharp and scour well. Both method and object are similar. Under these conditions if the cutting edge is not true, it must be ground until the edge is straight and sharp.

The practice of overlaying road grader blades is still too new to have developed standard methods in this connection and the welder will have to use his own judgment, taking into consideration the kind of material the grader is to handle and the surface conditions of the road to be graded. As more overlay metal is applied to road grader blades and experience with these overlays is increased, standard practice will, without doubt, be developed and be recognized by those in charge of such equipment.

Overlaying Scarifier Teeth

Scarifiers are used to break up the surface of the road so that a new surface may be graded upon it. In new construction the scarifier breaks up the surface of the soil in front of the grader blade. Figure 17 shows a combination grader and scarifier. The scarifier teeth are clearly indicated in this figure. Figure 20 shows a pair of scarifier teeth overlaid with Borium. It will be noted in this figure that the Borium is heavily overlaid on the front edge of the tooth. It should extend upward about six inches from the point of the tooth to prevent the rocks and dirt which are thrown against the tooth from wearing away a section of steel just above the Borium overlay, as indicated in Figure 21, where the overlay was too short.

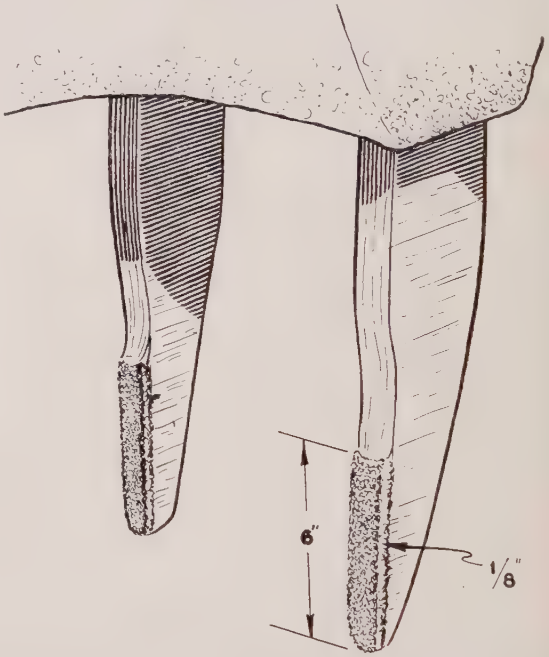


Figure 20—The Teeth of the Scarifier are Shown in this Sketch Overlaid with a Hard Surfacing Alloy. The Hard Surface Should be Welded to the Tooth at Least Six Inches Above the Point of the Tooth to Prevent Stones and Dirt from Wearing the Tooth as Indicated in Figure 21.

Scarifier teeth may be preheated before applying the overlay in a blacksmith forge, several of the teeth being heated at a time and kept hot until the welder is ready to overlay the tooth. He can then take a hot tooth from the fire, place it upon some firebrick on the table, using a couple of bricks to retain the heat, and apply the Borium to the preheated part. In the case of scarifier teeth, like all other parts, the Borium overlay must be welded to the surface of the tooth. As the service which these teeth are called upon to render is very severe, the Borium overlay should be heavy and be placed only on the front surface of the tooth. Under these circumstances the tooth is self-sharpening and will dig into the road or surface soil very efficiently.

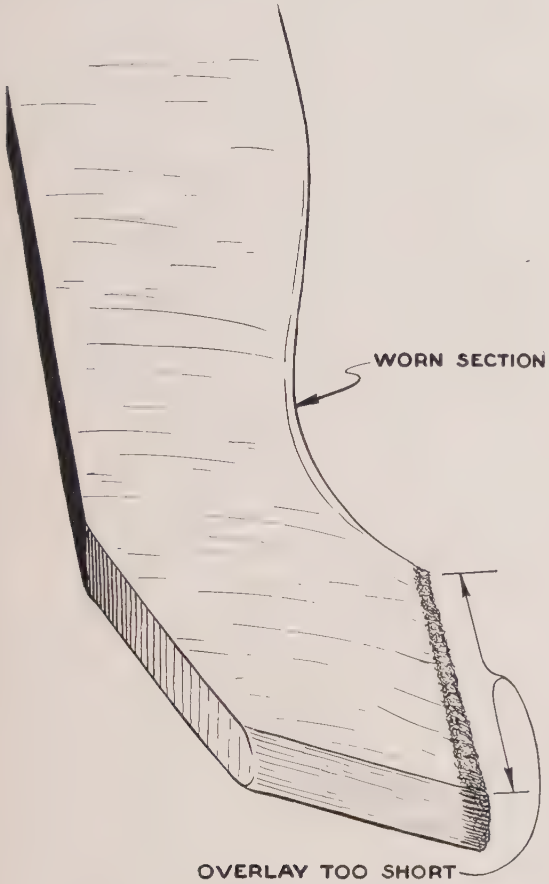


Figure 21—Sketch Showing the Result of Welding Too Short an Overlay on a Scarifier Tooth. The Steel Above the Overlay Wears Away From the Action of the Stones and the Dirt.

The application of any other overlay metal to scarifier teeth would be the same and would be efficient, depending of course upon the hardness, the toughness and abrasion-resisting characteristics of the overlay metal. Tube Borium has the great hardness of tungsten carbide imbedded in a tough steel matrix surrounding the particles of Borium. Stellite, Stoody Rod, Silfram; and Haystellite Composition Rod, manufactured by the Haynes Stellite Company of Kokomo, Ind.; and many other hard surfacing metals may be used as overlays for road machinery if desired. The technique of applying any non-ferrous alloy varies slightly from that described in that the surface of the forged or rolled steel part is not actually melted but brought up to a sweating heat or until the surface has a glassy, greasy appearance. The base metal is preheated in the usual manner with a neutral oxy-acetylene flame or a furnace, where necessary, but when the overlay is applied, the torch is adjusted until the flame has a slight excess of acetylene. This method of application should be remembered and used when any non-ferrous alloys are encountered.

Application of Diamond Substitutes

The application of pea Borium and other tungsten-carbide diamond substitutes to drill bits is illustrated in Figure 22.

Borium in the pea size is mounted to fish-tail bits, discs and core shoes in the following manner:

The bits must first be cleaned of all hard-surfacing metal and ground until bright. A previous overlay of hard surfacing metal may be either melted or ground off. If the bit has been badly worn, it is built up to its original size, using high carbon steel. It is then ground again to remove scale and it is ready for the mounting of the Borium. Borium is weighed out in approximately the quantities given in Table 1 for various sizes of bits, discs or core shoes.

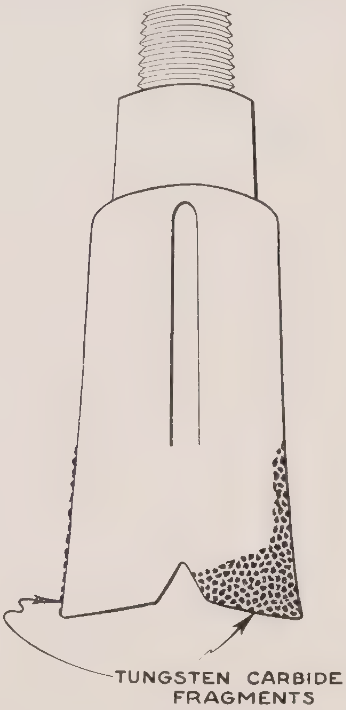


Figure 22—Tungsten Carbide Diamond Substitutes may be Mounted to the Exposed Surfaces of Drilling Bits and Coated Over with a Layer of Hard Surfacing Alloy. This Treatment is Much Less Expensive than the Use of Industrial Diamonds and Enables the Bit to Cut Through Even the Hardest Formation.

A large size tip should be used in the torch and the flame should be adjusted until neutral. The Borium is placed where it can be handily reached and a three-sixteenth inch high carbon rod is used to mount the Borium to the bit. A small spot where the Borium is to be mounted is heated to a red heat and the end of the high carbon rod is brought to the point of fusion. The rod is then touched to a Borium fragment which will adhere to it. The fragment is placed on the red hot spot and the surface of the bit fused around the Borium particle. Other fragments are set in this manner in rows about one-half inch apart and are completely surrounded by the molten high carbon steel. Several rows are applied and the alternate rows are staggered.

The pea Borium is thus mounted over the surface of the bit which is to be protected as shown in Figure 22. Stoodite, or other hard facing alloys are then used to completely cover this portion of the bit to a depth of from one-eighth to three-sixteenths of an inch.

Table 1

Amounts of Borium Recommended for Various Sizes of Drilling Bits

Fishtails

4¼"	2¾ ounces
5⅝"	3½ ounces
7⅝"	4½ ounces
9¾"	5¼ ounces
10⅝"	6 ounces
11¾"	7½ ounces
15"	10½ ounces
17" and 18"	12 ounces
19" and 20"	15 ounces
22" and 24"	18 ounces

Discs

6"	2¾ ounces each
8"	3 ounces each
9"	3¾ ounces each
10"	4½ ounces each
11"	5¼ ounces each
12"	6 ounces each
14"	7½ ounces each
16"	9 ounces each

Core Shoes

4¼"	2¾ ounces
5⅝"	3 ounces
6⅝"	3½ ounces
7⅝"	4 ounces
8½"	4½ ounces
9¾"	5 ounces
10⅝"	5½ ounces

NOTE—The figures given above are recommended for drilling under average conditions. If extremely hard formations are encountered, these figures should be increased about fifty per cent.

Building Up Manganese Steel Castings

Manganese steel expands and contracts during heating and cooling more than any of the other metals ordinarily used. As it solidifies from the molten state, it shrinks or contracts five sixteenths of an inch per foot. This considerable expansion and great shrinkage during solidification explains one of the difficulties encountered in the welding of manganese castings.

In many instances, particularly in connection with large manganese castings, it is believed that the electric arc will produce a more satisfactory job than the torch. Under the best conditions the welding of manganese steel is not altogether satisfactory, and every welder who has had much experience of this kind well remembers the difficulties which he has encountered when he has attempted to weld or build on to this unruly metal. The reasons for these difficulties lie in the peculiar characteristics of manganese steel which are given upon page 154. As stated upon this page, manganese steel must be rapidly cooled from its critical temperature, about 1940 degrees Fahrenheit, by quenching it in water in order to retain its characteristic properties.

If the casting is small and can be heated up to this temperature, which is a yellow heat, allowing this heat to soak into the casting until it is heated all the way through, it may be possible to quench the casting, thereby duplicating, to some extent, the conditions of manufacture. The welder, however, has not the means to handle large castings in this manner and, if he does heat a large casting, the heat is uncertain and is not uniform. Furthermore, the difficulties of quenching become so great that it is almost impossible to do a good job.

When using the oxy-acetylene torch, particularly upon heavy sections of steel as in rock-crushing and other heavy machinery, it is almost always necessary to preheat the part to be built up to a dull red heat. If the part is such that this can be done and the whole mass quenched properly, the torch may be used for such work, particularly when a layer of manganese steel is to be built over the part.

In many instances, however, the part is so large or it is so fastened to other parts of the machine that it is more convenient to use the electric arc and avoid preheating or applying any more heat than is necessary to the steel. It should be remembered that in welding manganese steel great care must be taken to keep the casting cool and not to allow the heat to raise the general temperature of the casting any more than can be helped. Even under these conditions there are changes which take place in the metal immediately adjacent to the weld but the effect of this heat by constant cooling of the casting can be reduced to a minimum.

When using the arc, a small section of the part is built up, then quenched with a piece of waste tied to a stick and soaked in a pail of water, and finally hammered. Each bead as it is made is treated in this manner which helps to restore the characteristics of the manganese steel and the manganese rod.

With this knowledge in mind and that given on page 154, the welder must determine for himself which part of manganese steel should be built up with the torch and those which should be confined entirely to electric welding.

Welding rods of carbon steel will combine well with manganese steel but a very satisfactory rod is of manganese steel itself because of its peculiar characteristics. The part was originally made of manganese steel on account of the strength, toughness and resistance-to-pounding of this metal, and it is often best to weld on metal having similar characteristics.

The fabricated manganese steel rods manufactured by the Stoody Company are made in general, as shown in Figure 1, three-sixteenths of an inch in diameter and twenty-eight inches in length, for oxy-acetylene welding, and three-sixteenths of an inch in diameter and 14 inches in length, for electric welding. The rod consists of a shell or tube of steel containing the manganese alloy mixture within. These fabricated manganese steel rods deposit a manganese steel containing from twelve to fourteen percent of manganese. The analysis of the weld metal is typical of commercial manganese steel but due to the elimination of impurities, the rod produces a metal which has a denser grain and is slightly harder than the commercial manganese steel.

One of the principal things which the welder should remember in welding manganese steel is to work slowly, to stop welding now and then and give the metal a chance to cool. By being very deliberate, using water frequently for quenching, and hammering when necessary, there is assurance of some degree of success.

It should be remembered, however, in connection with quenching that many manganese steel welding rods and electrodes contain from three to five per cent of nickel and when these are used quenching should be avoided.

Other Applications of Overlays

There are so many pieces of machinery which can be overlaid with economy that a full list of them would be hard to obtain. A very limited number have been described in this chapter and it should be understood that there are many more such parts which it is likely will be increased in number with further development of the process of welding as applied to overlays. Harrow teeth, discs, tractor treads and many other parts of agricultural machinery and parts of contractors' machinery; rock crushing machinery; dredging and mining machinery, etc., can be economically overlaid with hard surfacing metals. The principles covering these operations have been set forth so that the welder will know how to go about almost any specific job. In some instances he will have to experiment to a certain extent to determine for himself the requirements of the job and the best manner in which the overlay may be applied.

Chapter No. 4

Welding Saws

WELDING large band saws with the oxy-acetylene torch is an application of the process which has been developed to some degree, especially in the saw filing rooms of the lumber companies of the Northwest. Opinions differ as to the details of the methods used for welding saws, but the basic principles are the same in most instances. There has been considerable experimental work carried on by the saw filers themselves, by the companies furnishing the welding apparatus and also by the saw manufacturers. This experimental work has produced a technique which, while it is generally similar, is too new to have developed into recognized standard practices. Saw steel is not all of the same analysis, the welding rods used differ to a considerable extent, and the service required of band saws is not always the same. For this reason it is believed that the saw filer who has undertaken welding must use his knowledge of saws and the service demanded of them to vary heat treatment and final tempering of the saw to produce the best results.

Saw Steel

The steel from which saws are made must differ to a considerable extent, depending upon the manufacturer and the age of the saw. If the welder uses old steel cut from an old saw to make repairs upon a new saw, he may have two different steels which he must weld together. An alloy used by one of the large saw manufacturers for making band saws has the following analysis:

Carbon	0.70
Manganese	0.30
Nickel	0.70
Chromium	0.15
Molybdenum	0.15

This steel is hard, strong and tough. It's breaking strength is about 190,000 pounds per square inch.

In manufacturing band saws the steel is heat treated by heating it to a bright red heat and quenching it in oil. Afterward the steel is heated up to six or seven hundred degrees and allowed to cool in air to draw the temper, or, in other words, to reduce the hardness to a point where the saw will be most serviceable. The exact temperatures of heat treating saws must vary with each manufacturer and the special alloys of which saws are made.

The welder will appreciate that when he attempts to weld pieces of saw steel together he completely changes the characteristics of the steel and produces a section of cast steel along the welded seam which has no great strength compared to the very high strength, toughness and flexibility of the original saw steel after it has been heat treated. Therefore, an ordinary weld made in the usual manner would not have sufficient strength or flexibility to be of much value for the severe service required of a saw.

Before the fusion welding of band saws was undertaken, it was the practice to repair breaks by silver soldering the scarfed edges as described upon page 214. This was accomplished with large band saws, as well as the smaller ones. The difference lay chiefly with the size of the jigs and the tongs, but the principles remained the same. While brazing is still used in a great many instances and produces an excellent result, welding has been applied more and more to band and circular saws with varying degrees of success, depending on the care, the skill and the knowledge of the welder.

Patents

Patents have been obtained upon certain applications of oxy-acetylene welding to band saws, one of these being Patent No. 1,503,310, issued July 29, 1924 to Carl L. Ericson of Longmeadow, Mass., and assigned to the American Saw and Manufacturing Company of Springfield, Mass. This patent claims especially the making of an oblique or diagonal butt weld across a band saw. It recognizes the weakness of a butt weld made at right angles to the edge of the saw and seeks to increase the strength of the weld by making it diagonally across the blade of the saw instead of at right angles. In this manner, when the saw is passed over the rolls, only a part of the weld at a time is subjected to the bending action. The particular method or technique of making the butt weld is not disclosed and includes either brazing or butt welding.

On June 25, 1929 a patent was issued to O. J. W. Lougheed of Portland, Oregon, being No. 1,718,746. This patent specifically describes a method or technique of welding band saws without the use of spelter or fluxes and consists of fusing small portions of the weld at a time with a small oxy-acetylene torch, first from one side of the saw and then from the other. A welding rod is used, similar to a high grade piano wire, and each weld is lightly hammered as it is made. There were four claims allowed, Claim No. 4 reading as follows: "A method of welding band saws consisting in fusing small areas of each meeting surface, first from one side and then from the opposite side of the blade, at the same point beginning the fusing at a point substantially midway, the longitudinal edges of the blade, adding fused material from a welding rod of fine piano wire, the hammering of each of the fused areas in cooling, the heating and hammering of the total weld when completed and finally the tempering of the completed weld." The other three claims vary in detail and with the descriptive matter appear to require the alternate welding, first on one side of the saw and then on the other, with the hammering of each small weld and the ultimate tempering of the weld to secure suitable hardness.

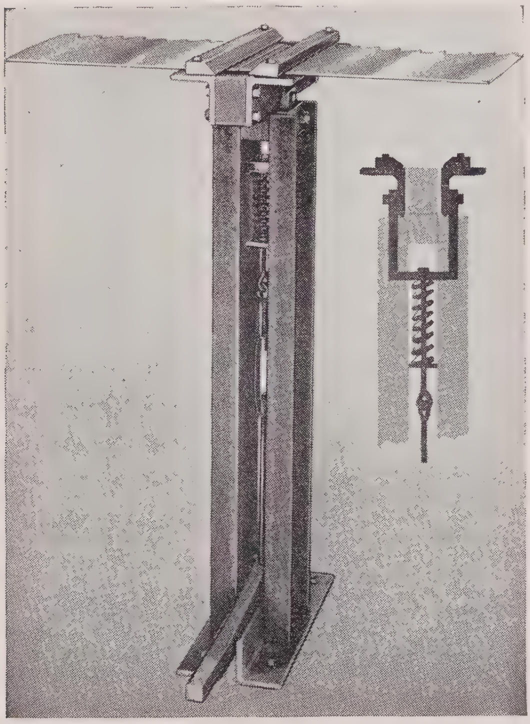


Figure 1—Drawing of a Jig for Welding Saws. In Its Normal Position the Saw is Held About One-Quarter of an Inch Above the Anvil. By Pressure Upon the Foot Lever, the Saw is Brought Down in Contact with the Anvil to be Hammered.

Fusion Welding Band Saws

A method which is employed in some of the lumber mills of Washington was described in an article published in the West Coast Lumberman in February 1931. One of the principal features of this method was the use of ingenious jigs and anvils. These jigs were in some cases "home-made" and differed in detail, but such jigs can now be obtained from manufacturers of saw mill equipment. A jig and anvil of this type is illustrated in Figure 1. It consists of a supporting stand made of channel bars bolted securely to the lower portion of the anvil. The anvil is thus rigidly supported from the floor. The jig, or clamp, is made of angle bars surrounding the anvil and bolted at each end to spacing blocks to keep them apart. Attached to each angle bar on both sides of the jig are sliding guides, permitting the jig to be moved upward and downward with rods, a spring and a foot lever. On top of the jig are clamping bars and screws to securely hold the band saw in position.

When the broken band saw is clamped into the jig, its normal position is about one-quarter of an inch above the anvil. By pressing on the foot lever, the saw and jig are moved downward until the saw is in contact with the anvil. The first position is ideal for welding, because no heat is conducted away from the saw as would be the case if it were constantly in contact with the anvil. By quick pressure of the foot on the foot lever, the small red hot spot which has been welded in the saw can be lowered into contact with the anvil to be hammered.

It is realized what physical difficulties would be encountered if it were necessary to turn a large saw, perhaps fourteen inches in width and fifty or seventy-five feet in length, completely over each time a weld was made. The practice described, therefore, includes the bevelling of the edges to be joined, of saws fourteen gauge in thickness and over, to an angle of forty-five degrees, as previously illustrated in the lessons. The ends of the saw are then placed in the jig and clamped securely in position. Welding is done entirely from one side. About three-eighths of an inch of the seam in the center of the saw is fused with a very small oxy-acetylene torch and tip and the weld is built up to the full thickness

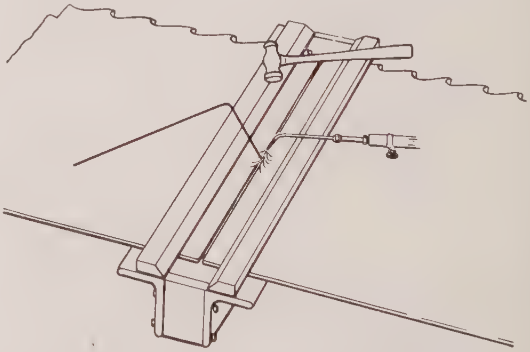


Figure 2—This is a Top View of the Anvil, Showing the Seam Across the Saw and the Weld in the Center of the Seam. A Spot Three-Eighths of an Inch in Length is Welded, the Saw Moved Down over the Anvil and the Weld Hammered.

of the steel with a special welding rod. When this three-eighths inch section is completed, the saw is lowered upon the anvil and hammered with a light hammer. This method is clearly illustrated in Figure 2.

The foot lever is then released and an adjacent three-eighths inch section welded in similar manner, lowered to the anvil and hammered, as just described. Next on the opposite side of the first weld made another three-eighths inch weld is made, care being taken to release the pressure upon the foot lever so that welding is not done while the saw is in contact with the anvil. This third weld is likewise hammered and the process repeats itself upon alternate sides of the first center weld until the ends of the seam at the edges of the saw are reached. This method is illustrated in Figure 3.

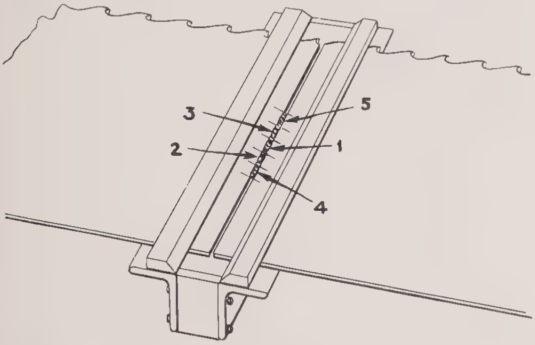


Figure 3—The First Weld is Made in the Center of the Seam. The Second is Made on One Side of the First Weld and the Third on the Other Side. The Torch is then Moved to the Part of the Seam Adjacent Weld No. 2 and Weld No. 4 is made. No. 5 is Made Adjacent to No. 3, as Shown and this Alternate Welding Proceeds Until the Ends of the Seam Are Reached.

When the ends of the saw were first placed in the jig, a slight spacing, about one-thirty-second of an inch, was left between the thin bevelled edges of the steel. This distance should not be too great, but it must be enough to prevent the crowding of the saw as the weld progresses each way from the center toward the edges. If too much crowding occurs, the edges may be spread by resorting to the methods described in Figures 14 and 15, shown respectively on pages 307 and 308. While the description is, in this instance, in connection with boilers, the same principle may be applied to the spreading of the edges of the seam in the saw. If it appears that one-half of the seam has a tendency to crowd, welding may be discontinued for the time being on this half and continued on the opposite half. By skilful manipulation of the heat in this manner, it is usually possible to keep the seam open until the edges have been reached.

Burning the Steel Must Be Avoided

Care must be taken to prevent burning. One of the most important matters in welding saw steel is to avoid overheating or burning the steel. Saw steel is higher in carbon than the steels usually welded, and burning of the steel takes place very easily. Holding the torch too long in any one position, or heating too large an area at a time, will burn the metal. After a little practice, the welder can tell, almost instantly by its appearance, when he has burned the steel. The steel will begin to boil, it loses its glossy, smooth surface and becomes gray and porous.

It is essential, therefore, that particular pains be taken with the flame. It should always be adjusted so that there is just a little excess of acetylene, not really a carbonizing flame, but distinctly on the carbonizing side of neutral. This adjustment avoids the possibility of the flame becoming oxidizing, without the welder knowing it, and helps to prevent burning the steel. Although fluxes are sometimes recommended for welding high carbon steel, they have so far proved of little value for saw welding. They produce a brilliant light which prevents the welder from seeing what he is doing, as well as he can without them. They do not materially help the steel. If the right kind of welding rod is used, oxidation is not of so much importance as overheating and burning the steel.

An excellent practice recommended by one saw welder, to prevent the inclusion of oxide in the weld, is to snip off the end from the welding rod with a pair of cutting pliers each time a new section of weld is made.

After welding a spot about three-eighths of an inch in length, the torch is placed in the left hand with the welding rod and the hammer is picked up in the right hand and used for forging. This exposes the red hot end of the welding rod to the air, if the rod is of high carbon steel, it will oxidize rapidly, leaving a ball of oxide on the end of the rod. If this oxide is fused into the weld, these particles will weaken the steel where they are included and should be avoided. It only takes a moment to snip off the end of the welding rod with the pliers and continue each weld with a fresh end of welding rod. Under these circumstances there is no possibility of including oxide in the weld from the rod and the ultimate result will be more satisfactory. This practice may, of course, be more necessary with certain rods than with others, but the practice does not involve any serious difficulties and undoubtedly does prevent inclusion of oxide, from this source, in the weld metal.

If a burned weld in saw steel is broken, burned areas are indicated by black surfaces. When the work has been properly done, as described; welding only a small area at a time; making the weld as rapidly as possible; moving the torch away just as quickly as the welding rod and saw are completely fused; and hammering the weld on the anvil; a break through the weld will show a fine grained weld metal and it will have a bright gray appearance. If the steel has been burned, however, the area will be black with evident indications of burning. When the steel has once been burned, it is believed to be better practice to cut the weld out of the saw entirely and insert a new piece, rather than to attempt to restore the steel by any means of heating and hammering.

Another method of welding a butt seam in a band saw is illustrated in Figure 4. The figures given are for a fourteen-inch band and the method has been suggested by one of the large saw manufacturing companies. When the ends of the saw are placed in the jig, the edges of the seam are set in contact, as shown at C, on the toothed side of the band. The back end of the seam, shown at B, is spaced about three-sixteenths of an inch for a fourteen-inch band.

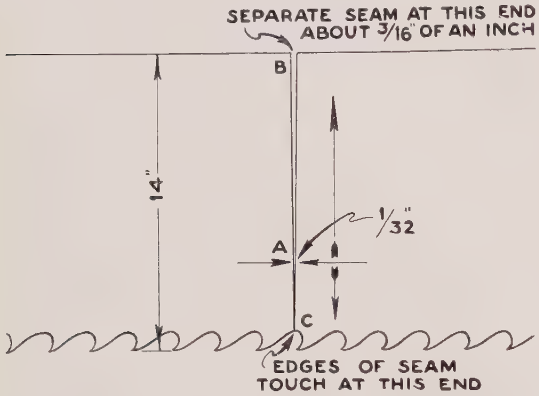


Figure 4—Sketch Showing a Method of Welding a Band Saw Using the Principles Described on Page 90.

Welding is started at A, where the separation in the seam is about one-thirty-second of an inch and is continued in the direction of the arrow toward B. About three-quarters of an inch in length is welded and the seam is lowered on the anvil and hammered. Another three-quarters of an inch is welded and hammered and so on until the weld is completed at B. Welding is then again started at A and three-quarters of an inch welded towards C, after which the weld is forged and continued in this manner until the edge at C is reached.

The clamping bars of the jig, of course, are not so tight that the seam will not draw together at B, as the weld approaches it. When B is reached, it will be found that C is open. The weld again started at A will close the seam at C as it approaches it. This company states that this method produces a straight saw and that the warpage is less. They also say that, under these conditions, it is unnecessary to bevel the edges of the steel before welding.

Welding Rods

Many different kinds of welding rods have been tried for saw steel with varying degrees of success. The article quoted in the beginning of this chapter mentioned music wire; Society of Automotive Engineers 4130 chrome, molybdenum steel, having a carbon content of 0.35 to 0.45; strips cut from band saws; high carbon drill rods; one-sixteenth inch strands from Roebling's blue center cable; and Swedish steel wire. One firm in the Northwest is selling an English steel of high grade. S. A. E. 3140 steel, having the following chemical composition, has been used:

Carbon	0.35 to 0.45
Manganese	0.50 to 0.80
Phosphorus	0.04 Max.
Sulphur	0.045 Max.
Nickel	1.00 to 1.50
Chromium	0.45 to 0.75

Many other steel alloys have without doubt been tried.

The author has welded a considerable number of specimen pieces of saw steel with various welding rods and under varying conditions of procedure. These specimens have been broken and the broken sections carefully examined to determine the burning of the steel, the grain size, inclusions of slag, etc. These experiments have indicated that a very good welding rod for saw steel is the chrome-vanadium steel, shown as No. 6, page 155. This steel has an analysis as follows:

Chromium	0.80 to 1.10
Vanadium	0.15 to 0.18
Carbon	0.40 to 0.50
Manganese	0.50 to 0.80
Phosphorus	0.04 Max.
Sulphur	0.04 Max.

This steel flows well under the flame, does not oxidize as much as some of the other steels and forges well. It does not crack during forging and is strong when heat treated.

Vanadium in steel has a deoxidizing effect and to a certain extent is also degasifying. It may be that these factors are not of particular importance, but the welder will appreciate the manner in which this steel flows under the torch and its forging qualities.

A considerable number of welds made with chrome-molybdenum steel of the analysis given on page 276 showed a tendency to crack during forging. Nickel steel of the analysis given under No. 5, page 155, also had a tendency to crack during forging. Drill rods burned very easily, and the surface oxidized to a considerable extent. S. A. E. 3140 steel produced a film of oxide over the surface, which was objectionable. This may have been a local condition and not the result of the steel itself. Sometimes the surface treatment of welding rods will produce this result.

It is not the purpose of the author to recommend any particular type of rod, because, as stated previously, the art of saw welding is too new to have developed standard practices in this connection. The welder will have to choose for himself the rod which he uses, and it will depend somewhat upon the analysis of the saw steel and the availability of the welding rod. There are undoubtedly other alloy steels which may produce excellent results and special rods may be developed for the purpose. With these remarks, however, the welder will understand more clearly the requirements of saw welding and will be better able to choose for himself.

Heat Treatment

This is a subject of much importance in connection with saw welding. Saws are heat treated when manufactured to obtain the great strength, toughness and flexibility required for the service which they perform. A band saw revolves over rolls at high speed and under considerable tension. Heat treatment consists in heating the saw held securely in presses, rolls or clamps, and when the steel is at the right temperature, lowering the saw and the press into a bath of oil. Quenching in this manner strengthens and hardens the steel until it is glass hard and can be easily broken. Afterward the temper is drawn by heating the saw, still held securely to prevent warping, to a blue heat or more, depending upon conditions, to give the saw the right temper and flexibility. After this second heating the saw is cooled in the air. Of course, heat treating practice differs in detail with different manufacturers and different kinds of saws and saw steel.

Furthermore, after heat treating, saws are tensioned by hammering and by rolling and stretching to give the saw a slight depression at the center as it curves over the lower roll. The tensioning of a saw is a skillful job which is understood by every good saw filer and it is not the intention to discuss this treatment of saws in this chapter. The welder should understand, however, that when he has completed welding the saw, he has not completed the full procedure by any means. Both heat treatment and the proper tensioning of the area of the joint are essential to the production of a successful job.

The practice of some of the northwestern mills has been to heat the area of the weld between the bars of the jig, while the saw is securely held in the jig, to a dull red and allow the saw to cool in the air. The method of welding, that is, welding a small spot and hammering must, of necessity, place a good many strains in the steel. These strains are adjusted somewhat by heating to a dull red heat and allowing the steel to air cool. When the steel is cold, the weld is ground with a flexible shaft grinder and a wire brush until bright. While still in the jig, the torch is again applied to the area between the clamping bars until the steel is at a blue heat. When the heat is just right, water is applied to the saw blade to quench it, thus tempering the weld to a certain extent. This treatment is claimed to produce successful results and saws so welded have given excellent service.

In the author's experiments, the original heat treatment of the saw was duplicated, as far as possible, with the comparatively crude methods of heating and judging the temperature necessary when using a torch and quenching with water in a jig. It would, of course, be better if it were possible to heat treat the area of the weld while held in suitable clamping devices, in furnaces, controlled by accurate pyrometers, as originally used in the manufacture of the saws. This equipment, however, is not normally available to the saw filer who is repairing saws at a mill and he must, therefore, substitute methods which will approximate the ideal conditions as closely as possible. It is recognized that heat treatment under such conditions is far from an accurate procedure, but there is little doubt that the strength, toughness and the final temper of the saw can be greatly improved, by these methods, after welding.

The specimens referred to were heat treated by various means. Some were heated to a dull red and allowed to cool in the air, afterwards being heated to a blue heat and quenched. Others were heated to a bright red heat and quenched with water, by applying a water soaked cloth to the saw blade while it remained in the jig. The temper was afterwards drawn by heating to just above a blue heat and allowing the saw to cool in the air. This later method seemed to produce the strongest and toughest specimens which were made. They were broken with greater difficulty and the weld metal showed a fine grain and a clean break. The first heat given to the saw was an orange red. The second heat was above a blue heat, just sufficient to char a stick of soft wood, but not to set it on fire.

In order to prevent warping of the saw during these operations, the jig must securely hold it in place and must be heavy enough to prevent warpage of the jig bars and other members caused by the heat absorbed by these parts.

The engineers of one of the large saw manufacturing companies believe that heating a weld, after it has been completed, to approximately a red heat with a torch may be a dangerous practice, unless very carefully done, because of the probability of irregular heating and the chances of cracking the steel. These cracks may be very minute and hardly visible to the eye, but nevertheless, present in the weld or adjacent to it.

These men believe that a safer way to apply heat is to heat an iron of the right width and length to fit in between the jig bars, to a temperature of approximately 1,600 degrees and apply the heat to the welded band by placing the irons over the weld. This method is, without doubt, likely to produce more even heat throughout the band than would be the case with the torch. If heating is evenly done with irons, as described, and the clamps are not too tight, they believe the steel may be quenched with a wet cloth without danger to it. Reheating after welding must always be done slowly and as uniformly as possible.

The method of heat treatment which the welder will use and the temperatures at which he quenches or tempers the steel will depend, to a large extent, upon his own experience in the care of saws and the equipment which he has available. It is not intended in this chapter to recommend a definite procedure for heat treatment, because it is not believed that enough experience has yet been gained in saw welding to develop a standard method. Such a procedure will ultimately be the outcome of practice as saw welding becomes more common.

Welding Teeth and Cracks in Saws

The description given for the welding of a butt weld clear across a band saw has been taken as an example because it is, without doubt, the most difficult weld in a band saw which can be made. Cracks which appear in a saw can be welded with much less difficulty and teeth may be welded in place without much trouble. In a great majority of instances welding will include the welding of cracks in the saw and the welding of new teeth to replace old ones. Butt welds in band saws require more than ordinary skill, and will not usually be undertaken by a welder until after he has had considerable experience in welding cracks and teeth.

Welders are cautioned that the breaking of a saw in operation may cause very serious consequences, and unless the welder has had sufficient training to know that he can do a satisfactory job of butt welding, he should confine his efforts entirely to the welding of cracks and teeth. Teeth are cut from old saws, inserted in the edge of the saw and welded into position. The same jig may be used, which has been described, or special jigs, or attachments for this jig may be developed as required.

The flame of the torch should be held so that it points towards the body of the saw and not towards the tooth. The body of the saw will then absorb much of the heat without injury, whereas if the flame were pointed towards the end of the tooth, the steel would be overheated and probably burned. Great care must be taken to prevent overheating of the tooth.

Cracks in band saws should be started, as hereafter described for circular saws, from the inner end of the crack. The method of welding is similar to that described for butt welding. That is, the welding of a small spot three-eights of an inch in length and forging on the anvil, with the hammer.

A welder often has difficulty in preventing the burning of the edge of the saw when he reaches the end of a seam. This can be prevented by taking a small piece of saw steel, slightly more than one inch square, or shaped to fit the curved edge of the saw between teeth and placing this small piece of steel at the end of the seam. It should be tack welded in position and when the seam is completed, the weld should be continued into this piece. It will help to absorb the heat of the flame and will avoid burning the edge. The piece may be cut off after the weld has been completed.

Testing

Students of saw welding should have some means to determine the quality of welds made in saw steel. One method, recently used in a saw welding school, was the cutting of strips of steel from the saw sixteen inches in length and two inches in width, with the weld directly in the middle of the piece. One end of this strip of saw steel was placed in a vise in an upright position. The other end was clamped in the jaws of a monkey wrench and the piece was bent backward and forward repeatedly to angles of forty-five degrees. A good saw weld will show no ill effects from this treatment and will come back to an upright position. Twenty-four inch strips, also two inches wide, cut in similar manner from the saw steel should repeatedly bend in a half circle and come back to an upright position. The sixteen inch piece should stand twisting of 120 degrees without checking.

As a final test the weld should be broken directly through the weld metal. The cross-section of the weld should then be examined for burned spots, shown as black areas; for inclusions of oxide and for the fineness of the grain structure. A good weld will show a fine grain, similar in general to the grain of the original steel. If the grain is coarse, the weld metal will not possess great strength. The welder should break a piece of the original saw steel and compare the grain of this steel with that of the weld metal. In this way he can quickly obtain a definite idea of grain size which he will strive to obtain. He will also clearly visualize the appearance of the broken section of the original steel. This fracture of the original steel may represent the standard which he is trying to approach, both in grain size and general appearance.

Circular Saws

In general, saw teeth and cracks in circular saws are welded in much the same manner as band saws. A rim crack in a circular saw may be welded from both sides, the saw being turned over quickly after the first weld is made. A circular saw, unless it is too large, can be handled in this manner with proper equipment and sufficient help. In accordance with principles expressed previously in the lessons, the weld should start at the inner edge of the crack and work should be carried towards the rim. A small spot should be welded and hammered. As the torch is applied to the steel, the saw will buckle upwards slightly and the weld should be made about half way through the thickness of the steel. The saw is then turned over and a weld made from the opposite side half way through the steel. Hammering tends to straighten out the buckle and by turning the saw from side to side and proceeding in this manner, a weld may be made to the edge of the saw without causing serious distortion. Teeth may be welded in as heretofore described, using teeth cut for the purpose from an old saw.

Chapter No. 5

Miscellaneous Data, Applications, Methods, Etc.

CUTTING a piece of wire rope would seem to be a very simple operation and most welders without thought would choose the cutting torch as the proper means to cut the rope. The cutting torch will cut the rope very easily, but the wire strands of the rope as they are cut will fly apart and untwist, making an end, which is hard to handle.

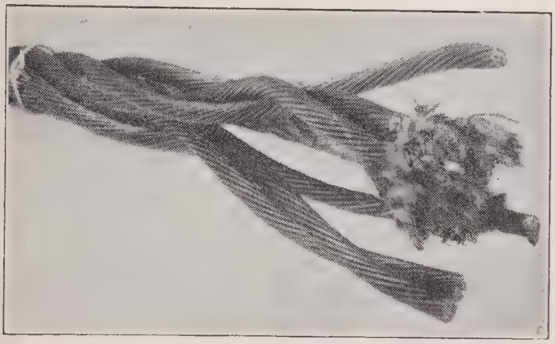


Figure 1—A Piece of Seven-Eighths Inch Wire Cable Which has been Cut with the Cutting Torch. Note the Untwisted Ends of the Strand.

If the operator will select the welding torch instead of the cutting torch, and melt through the strands of the wire rope, he can at the same time weld them together, making an end, which is easy to handle and is better than a bound end. It entirely avoids untwisting of the wire strands. The size of tip to use depends upon the diameter of the rope and the welder will know at a glance how large the tip should be.

Sickness Caused by Brazing and Welding Galvanized Iron

Fumes, caused by welding and brazing galvanized steel are injurious. In welding or brazing galvanized parts, fumes are caused by the burning of the galvanized coating of zinc from the steel, which rise from the seam being welded in a white cloud. It is injurious to the welder to breathe these fumes, which are the result of the volatilization of the zinc in the flame of the torch.

Zinc melts at 786 degrees Fahrenheit and boils at 1665 degrees Fahrenheit. As the metal boils, when heated by the flame, zinc vapors are produced in large quantity. These vapors burn, and, as they come in contact with the air, produce white fumes in the form of zinc oxide, which may be breathed by the operator.

The same reaction takes place when welding brass, as the zinc content of the brass is volatilized in similar manner.

The welder, therefore, must protect himself in some way if he has very much welding to do, either upon brass or upon galvanized iron. A good way to accomplish this is to arrange an exhaust fan and an ordinary electric fan in such relation to the work that the fumes will be carried to the exhaust fan as they are produced, and the welder will be kept free from them. A welder may, if he desires, wear a simple gas mask, consisting of a rubber mouth and nose piece, with a wet sponge inserted therein. These are not very comfortable, however, and if it is possible to install a good arrangement of fans, it will be the most satisfactory way to prevent sickness of the welder.

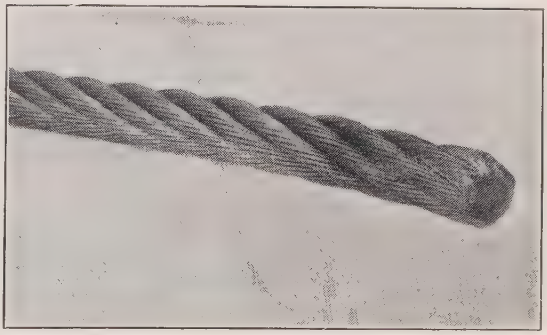


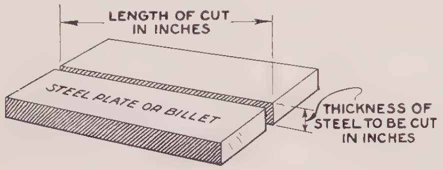
Figure 2—Photograph Showing a Piece of One Inch Wire Cable Melted Through with the Welding Torch. The Strands are Not Untwisted and They are Closely Welded Together Making an Excellent End.

Breathing these fumes to any great extent is likely to bring on chills followed by fever which may often be prevented by drinking a considerable quantity of milk. It is, of course, always best to consult a doctor under such conditions, but in some instances welders who have been subjected to zinc oxide fumes have made a practice of counteracting the effects of these fumes by drinking milk and in this manner they believe have saved themselves the resulting sickness.

Approximate Method for Estimating Gases and Time Required for Cutting Steel

The oxygen required for cutting in cubic feet equals the length of the cut in inches, multiplied by the thickness of the steel in inches, and divided by two.

The acetylene required for cutting in cubic feet equals the length of the cut in inches, multiplied by the thickness of the steel in inches, and divided by twelve.



The time required to cut in minutes equals the length of the cut in inches, multiplied by the thickness of the plate in inches, and divided by four.

These figures are, of course, approximate, but will serve to give a general idea which is accurate enough for many purposes.

Cutting Steel Plate

Tables 1, 2 and 3 give figures which will be found very useful in determining the amount of oxygen, acetylene and the time required for cutting steel plate of various thicknesses. The consumption figures of oxygen and acetylene for each number of tip were very accurately determined by actually operating the tip for predetermined periods of time and weighing the gas consumed from the cylinders. The scales used were especially made for the purpose and consisted of a beam balanced on accurate bearings at the top of a central post.

Two cylinders were supported from the ends of the beam and a long indicating pointer was rigidly attached to the beam center. Regulators were attached to the cylinders and prior to the test, the beam was exactly balanced with the pointer pointing to a fine arrow on a fixed scale. Hose was then attached and the torch burned for a definite period under pressures determined upon

Table 1

Approximate Cutting Table Showing Thickness of Steel, Size of Tip, Oxygen and Acetylene Pressures and Speed of Cutting

Thickness of Steel in Inches	Number of Tip	Drill Size of Oxygen Cutting Jet	Oxygen Pressure Lbs. Per Sq. Inch	Acetylene Pressure Lbs. Per Sq. Inch	Cutting Speed Inches Per Minute
¼	1-4	56	10-15	3	18-20
½	2-4	54	15-20	3½	15-18
1	3-4	52	20-25	4	10-12
2	4-4	48	25-30	5	8
3	4-4	48	30-35	5	7
4	5-4	43	35-40	5	6
6	6-4	38	45-50	5	4
8	6-4	38	65-75	5	3

Table 2

Table Showing the Consumption of Oxygen and Acetylene in Cubic Feet in the Preheating Flames of the Cutting Tip

Tip Number	Oxygen Pressure Lbs. Per Sq. Inch	Acetylene Pressure Lbs. Per Sq. Inch	Oxygen Cu. Ft. Per Hour	Acetylene Cu. Ft. Per Hour
1-4	3	3	10	10
2-4	3½	3½	17	17
3-4	4	4	28	28
4-4	5	5	38	38
5-4	5	5	54	54
6-4	5	5	54	54

Table 3

Table Showing the Deliveries of Oxygen in Cubic Feet per Hour Through the Cutting Port of the Cutting Tips at Various Pressures

	Pounds Per Square Inch									
Tip No.	10	20	30	40	50	60	70	80	90	100
1-4	31	49	69	87	97	119	130	134	165	168
2-4	40	66	91	105	121	145	178	201	210	230
3-4	74	111	134	150	186	207	276	289	311	337
4-4	93	132	165	219	271	344	368	414	447	512
5-4	121	149	220	275	341	404	439	503	558	617
6-4	160	228	296	387	467	497	606	636	741	824

a mercury gauge. At the end of the time limit the hose was removed from the regulator, attached to the cylinder from which the oxygen was being consumed, and the beam balanced with shot placed in a container for the purpose. The shot was then weighed and equalled the weight of gas withdrawn from the cylinder.

Tests for the consumption of both acetylene and oxygen were made in this manner and these weights converted into cubic feet. Pressures were very accurately determined with mercury columns and temperature and barometric pressures were given due consideration. The results are as accurate as they can be produced when using commercial tips.

Approximate Number* of Cast Iron Welding Rods in Ten Pounds

Sizes in Inches	Accurately Sized Square Rods	Accurately Sized Round Rods
3/16x20	54.9	70
7/32x24	33.3	42.7
1/4x24	25.6	31.9
5/16x24	16.4	20.8
3/8x24	11.4	14.5
1/2x24	6.5	8.2

**NOTE—These figures are mathematically correct, using the figure 0.26 lbs. per cu. in. as the weight of cast iron. Commercially cast rods are never exact in dimensions and will vary from the above figures.*

A factor which is not normally given consideration in making tests of this kind is the comparative inaccuracy in the actual drilling of tips. No two drills will cut ports of exactly the same size and a very slight variation in the areas of the ports will make a considerable difference in the discharge of gases through these ports under definitely set pressures.

As far as all practical purposes are concerned, the figures are sufficiently accurate, but in comparing them with other tables of similar nature, it should be understood that such figures at best represent the consumption of the particular tips tested and will vary with other tips of the same size and even of the same make.

There are many variable factors in cutting, the greatest of which are the speed of cutting and the oxygen pressure at which the cut is made. The gas consumption of the torch, per linear foot, will depend upon these figures as well as upon the size of the tip used. Pressures will depend upon the accuracy of the regulators and cutting speed upon the skill of the operator and the condition of the steel being cut. When cutting rusty steel covered with scale, the speed will, of course, be slower and the size of tip required larger than when cutting clean, new plate.

There is a definite relation between the speed of cutting, the size of the tip and the pressure at which the oxygen issues through the cutting jet. These speeds, of course, are governed by the rate of combustion of the steel and the oxygen as the cut progresses downward through the piece. If the forward speed of the torch is too rapid, there will be a "lag," as it is called to the cut and the lines of the cut will curve to the rear, as shown in Figure 6 on page 43. If the forward speed is much too rapid, combustion of the metal will not have the opportunity to extend clear through the piece and slag will blow out of the top of the cut instead of being forced downward clear through the section.

Some operators believe that they produce better results by using a small tip and a high pressure. Greater economy will result, however, if a larger tip is selected and the pressure of the oxygen is reduced. This may slow down the speed to a slight extent, but the consumption of oxygen will be less and the cut will be a smooth, more accurate cut. The selection of the tip sizes and the pressures of the oxygen, given in Table 1, are based upon this principle.

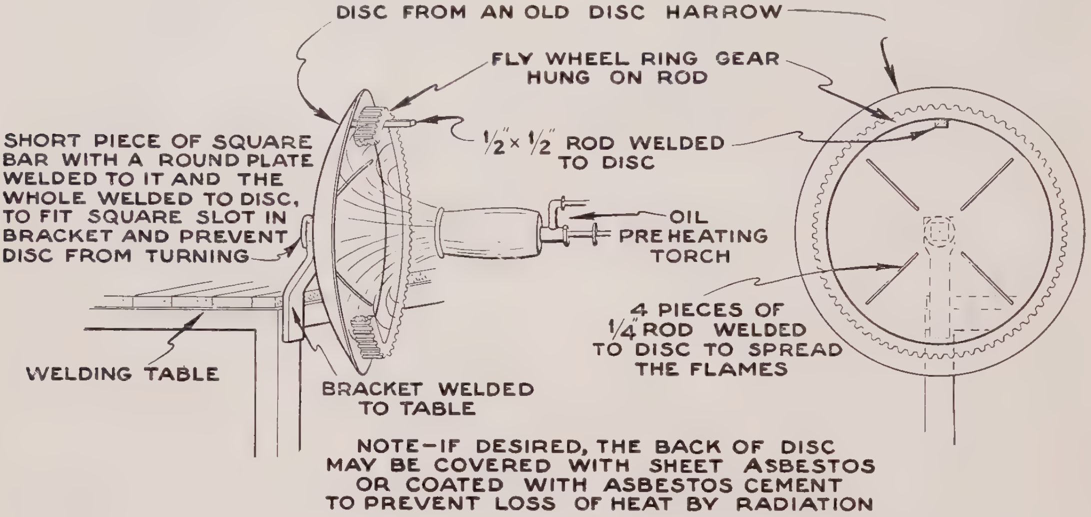
Approximate Number of Steel Welding Rods in Ten Pounds
Round Steel Rods, 36 Inches Long

Diameter, Inches	1/16	3/32	1/8	5/32	3/16	1/4	5/16	3/8	7/16	1/2
Approximate Number in 10 Pounds	320	142	80	51	35	20	13	9	6.5	5

Approximate Number of Non-ferrous Welding Rods in Ten Pounds
Round Rods, 36 Inches Long

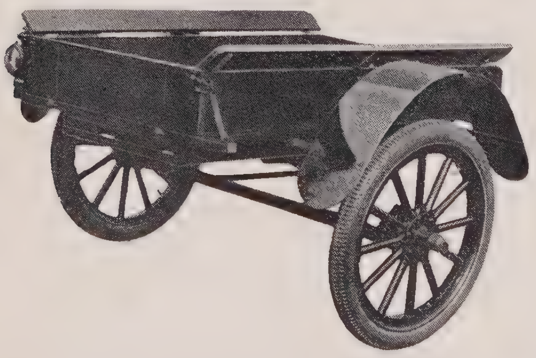
Diameter, Inches	3/32	1/8	5/32	3/16	1/4	5/16	3/8
Tobin Bronze	132.5	74.5	47.7	33.1	18.6	11.9	8.3
Manganese Bronze	133.1	74.9	47.9	33.3	18.7	12.0	8.3
Phosphor Bronze	125.4	70.5	45.1	31.3	17.6	11.3	7.8
Brazing Metal	132.6	74.6	47.7	33.1	18.6	11.9	8.3
Silicon Copper	126.3	71.0	45.5	31.6	17.8	11.4	7.9
Electrolytic Copper	125.1	70.4	45.1	31.3	17.6	11.3	7.8
Everdur	131.7	73.9	47.3	32.9	18.5	11.8	8.2
Naval Bronze	132.5	74.5	47.7	33.1	18.6	11.9	8.3

It is, of course, possible, for instance, to cut two inch steel with a smaller size tip than a 4-4. The oxygen pressure recommended with this tip, to cut two inch steel, is from twenty-five to thirty pounds. The speed given for such cutting is eight inches per minute. If a smaller tip is used, a higher pressure of oxygen must also be used to do the same cutting. It is possible to cut two inch steel with a No. 1-4 tip, or a 2-4, but the oxygen pressures must be much higher, the speed of cutting will be less and the cut may curve out of a vertical plane.


DISC FROM AN OLD DISC HARROW
FLY WHEEL RING GEAR HUNG ON ROD
SHORT PIECE OF SQUARE BAR WITH A ROUND PLATE WELDED TO IT AND THE WHOLE WELDED TO DISC, TO FIT SQUARE SLOT IN BRACKET AND PREVENT DISC FROM TURNING
½"×½" ROD WELDED TO DISC
OIL PREHEATING TORCH
4 PIECES OF ¼" ROD WELDED TO DISC TO SPREAD THE FLAMES
WELDING TABLE
BRACKET WELDED TO TABLE

NOTE—IF DESIRED, THE BACK OF DISC MAY BE COVERED WITH SHEET ASBESTOS OR COATED WITH ASBESTOS CEMENT TO PREVENT LOSS OF HEAT BY RADIATION

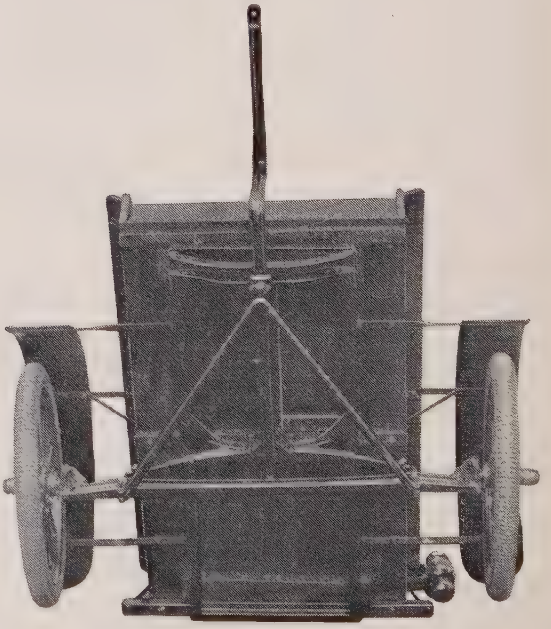
The figures given represent good practice in cutting under economical conditions, both as to gas and time consumption. Furthermore, the cut made in this manner, if the torch is mounted upon a machine, will be smooth, regular and accurate.



Expanding Fly-Wheel Ring Gears

An excellent method of expanding fly-wheel ring gears, in order to shrink them on the wheel, is shown in the illustration. This method utilizes a kerosene preheating torch, which is always useful around a welding shop, and will supply heat at much less expense than the burning of oxygen and acetylene or other more expensive gases. The kerosene burner produces a large bushy flame, which if properly deflected, can be utilized to evenly heat a fly-wheel ring gear as illustrated.

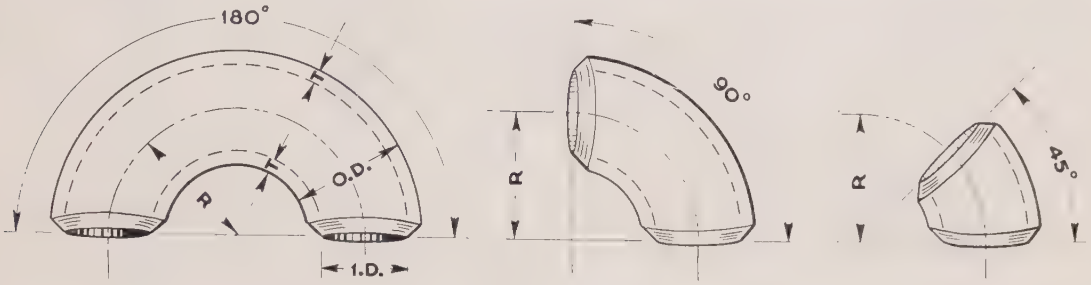
The deflector is made from an old harrow disc, which is mounted with a bracket to the welding table. A rod to support the ring gear is welded to the top of the disc and four pieces of rod are welded to the disc to act as spreaders for the flame. The construction is very simple and the illustration gives an excellent idea of what is intended. This ring gear heater has been used by some welding shops in the middle west to great advantage. The ring gear is evenly preheated and expanded and the arrangement is more convenient than attempting to heat it in a charcoal furnace or a forge.



A Welded Trailer Made of Ford Parts

In the two photographs, one showing a side view of the trailer and the other a bottom view, the welder will gain an idea of how a very good trailer can be made by utilizing parts of an old Ford car. This trailer is somewhat more elaborate than many which have been welded of Ford parts, but is an excellent example and made a very satisfactory job. It is unnecessary to list the various parts or to describe the job in detail, because the construction of such a trailer will depend largely upon the parts which the welder has available. He will have to use what he can get, and to make, from scrap steel, the necessary brackets, braces, draw-bars, etc., which he cannot secure from the dismantled Ford. Trailers of this type, when properly made, are strong and serviceable and will stand up under rough usage.

Sizes and Data for Tube Turns Manufactured by, TUBE TURNS, INC., Louisville, Ky.



Standard Thickness—IRON PIPE SIZES—Series 1½ R

Nominal Pipe Size	Radius Inches (R)	PIPE DIAMETER O. D.	PIPE DIAMETER I. D.	Wall Thickness (T)	Weight Pounds (180° Type)	Bursting Pressure Pounds
¾″	1⅛	1.050	0.824	.113	⅓	17,520
1″	1½	1.315	1.048	.134	¾	10,600
1¼″	1⅞	1.660	1.380	.140	1	8,770
1½″	2¼	1.900	1.610	.145	1½	7,940
2″	3	2.375	2.067	.154	2¾	6,355
2½″	3¾	2.875	2.469	.203	5¾	6,640
3″	4½	3.500	3.068	.216	9	5,800
3½″	5¼	4.000	3.548	.226	12½	5,310
4″	6	4.500	4.026	.237	17	4,950
5″	7½	5.563	5.047	.258	29	4,360
6″	9	6.625	6.065	.280	45	3,970
8″	12	8.625	7.981	.322	90	3,435
10″	15	10.750	10.020	.365	159	3,120
12″	18	12.750	12.000	.375	234	2,710
14″ OD	21	14.000	13.250	.375	300	2,465
16″ OD	24	16.000	15.250	.375	393	2,160
18″ OD	27	18.000	17.182	.409	544	2,090
20″ OD	20½	20.000	19.182	.409	458	1,880

Extra Heavy—IRON PIPE SIZES—Series 1½ Rx

Nominal Pipe Size	Radius Inches (R)	PIPE DIAMETER O. D.	PIPE DIAMETER I. D.	Wall Thickness (T)	Weight Pounds (180° Type)	Bursting Pressure Pounds
1½″	2¼	1.900	1.500	.200	2	10,300
2″	3	2.375	1.939	.218	4	8,630
2½″	3¾	2.875	2.323	.276	7½	9,025
3″	4½	3.500	2.900	.300	12	8,060
3½″	5¼	4.000	3.364	.318	17¼	7,315
4″	6	4.500	3.826	.337	24	6,890
5″	7½	5.563	4.813	.375	41	6,200
6″	9	6.625	5.761	.432	67	6,000
8″	12	8.625	7.625	.500	136	5,335
10″	15	10.750	9.750	.500	215	4,280
12″	18	12.750	11.750	.500	308	3,605
14″ OD	21	14.000	13.000	.500	396	3,285
16″ OD	24	16.000	15.062	.469	490	2,700

All stock sizes furnished with ends beveled 45 degrees for welding unless otherwise specified.

(See page 85 for further information)

The owner of a welding shop, rightly located for the sale of such equipment, could make such trailers in spare time and could, without doubt, market several of them during the season.

Phosphor Copper Welding Alloys

A phosphor copper alloy is made by the Westinghouse Electric and Manufacturing Company under patents owned by them for the brazing of phosphor bronze and other copper base alloys. It is called "Phos-Copper" and is furnished in cast rod, in rolled strips, and in drawn rod as may be required for various jobs. It is largely copper and contains from five to ten per cent of phosphorus. It begins to melt at about 1292 degrees Fahrenheit and becomes very fluid at 1382 degrees Fahrenheit for the rod and 1472 degrees Fahrenheit for the strips.

The rod contains slightly more phosphorus than the strips and this accounts for the lower melting point. Phosphorus in copper deoxidizes the metal, and depending upon the amount, lowers the melting point and makes the alloy flow more freely. Fluidity helps the alloy to penetrate and adhere with great tenacity, insuring a strong joint. Many copper base alloys can be brazed in this manner using Phos-copper as a substitute for silver solder. No flux is required as the phosphorus acts as a flux.

In applying phosphor copper, as in all other brazing, the surface must be absolutely clean of grease and oil. If the part can be dipped in acid prior to brazing, it is so much the better. A strip of phosphor copper is placed between the two parts and they are heated with the oxy-acetylene torch until the temperature is approximately 1475 or 1500 degrees Fahrenheit. This will fuse the phosphor copper strips.

If the alloy cannot be used in strip form, it can be in rod form, using the torch to heat the parts after they have been thoroughly cleaned and applying the rod, as usual in brazing, as a filler rod. It is essential that the part be brought to the proper temperature before applying the rod, otherwise a thorough amalgamation will not take place. Many parts can be brazed in this manner to advantage.

Flame Temperatures of Various Gases When Burned With Oxygen

Gas	Approximate Temperature Degrees Fahrenheit
Acetyiene	6,300*
Hydrogen	4,600
City Gas	4,400
Natural Gas (Methane)	4,200
Acetylene burned with air	3,230

*Given by some authorities as 5,800°.

British Thermal Units* Developed by Various Gases

Gas	Approximate B.T.U. per cu. ft.
Acetylene	1,650
Natural Gas (Methane)	1,000
City Gas	600
Hydrogen	350

*Heat units. See page 32.

Weight of Oxygen and Acetylene

(at 68° F. and atmospheric pressure of 30 in. of mercury)

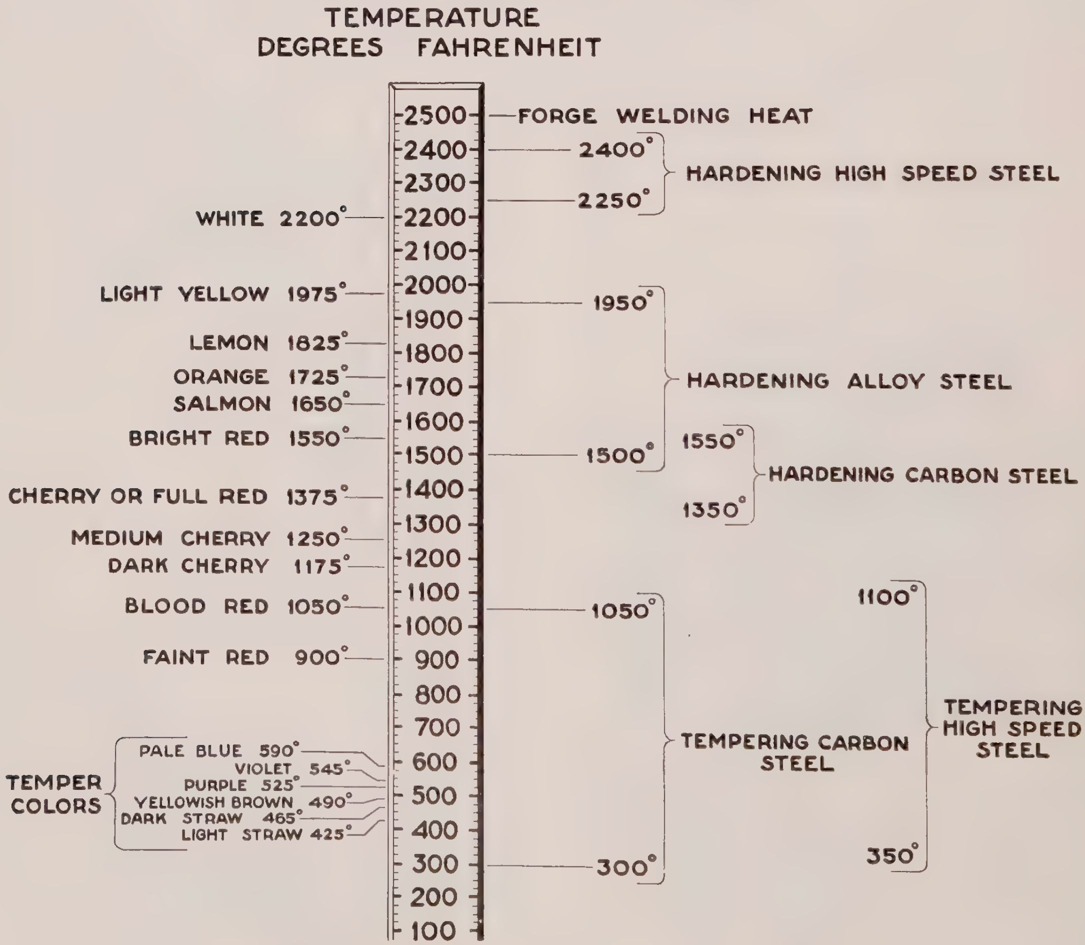
Oxygen

1 pound = 11.9988 cubic feet
1 ounce = 0.7499 cubic feet
1 cubic foot weighs 0.08334 pounds

Acetylene

1 pound = 14.5487 cubic feet
1 ounce = 0.9093 cubic feet
1 cubic foot weighs 0.06873 pounds

HEAT TREATMENT CHART

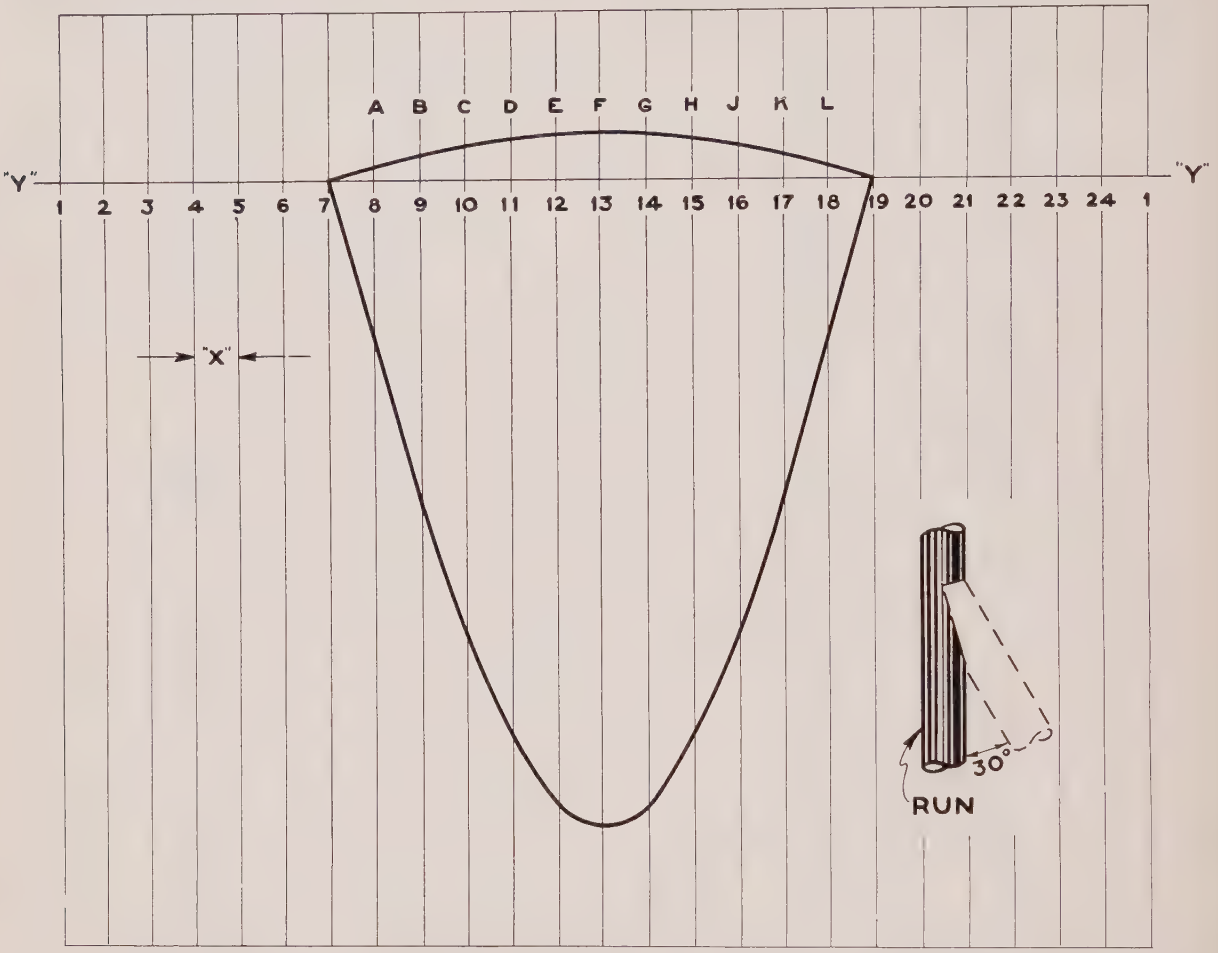

TEMPERATURE DEGREES FAHRENHEIT
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
FORGE WELDING HEAT
2400°
2250°
HARDENING HIGH SPEED STEEL
WHITE 2200°
LIGHT YELLOW 1975°
LEMON 1825°
ORANGE 1725°
SALMON 1650°
BRIGHT RED 1550°
CHERRY OR FULL RED 1375°
MEDIUM CHERRY 1250°
DARK CHERRY 1175°
BLOOD RED 1050°
FAINT RED 900°
1950°
1500°
HARDENING ALLOY STEEL
1550°
1350°
HARDENING CARBON STEEL
1050°
300°
TEMPERING CARBON STEEL
1100°
350°
TEMPERING HIGH SPEED STEEL
TEMPER COLORS
PALE BLUE 590°
VIOLET 545°
PURPLE 525°
YELLOWISH BROWN 490°
DARK STRAW 465°
LIGHT STRAW 425°

Diameters, Areas, and Morse Drill Gauge Sizes of Drill Holes

Diameter, Inches		Area Square Inch	Morse Drill Gauge Size	Diameter, Inches		Area Square Inch	Morse Drill Gauge Size
Fraction	Decimal			Fraction	Decimal		
	0.0135	0.000143	80		0.1695	0.0226	18
	0.0145	0.000165	79	11/64	0.1719	0.0232	
1/64	0.0156	0.00019			0.173	0.0235	17
	0.016	0.00020	78		0.177	0.0246	16
	0.018	0.00025	77		0.180	0.0254	15
	0.020	0.00031	76		0.182	0.0260	14
	0.021	0.00035	75		0.185	0.0269	13
	0.0225	0.00040	74	3/16	0.1875	0.0276	
	0.024	0.00045	73		0.189	0.0280	12
	0.025	0.00049	72		0.191	0.0286	11
	0.026	0.00053	71		0.1935	0.0294	10
	0.028	0.00062	70		0.196	0.0302	9
	0.0292	0.00067	69		0.199	0.0311	8
	0.031	0.00075	68		0.201	0.0317	7
1/32	0.0312	0.00076		13/64	0.203	0.0324	
	0.032	0.00080	67		0.204	0.0327	6
	0.033	0.00086	66		0.205	0.0332	5
	0.035	0.00096	65		0.209	0.0343	4
	0.036	0.00102	64		0.213	0.0356	3
	0.037	0.00108	63	7/32	0.2187	0.0375	
	0.038	0.00113	62		0.221	0.0384	2
	0.039	0.00119	61		0.228	0.0408	1
	0.040	0.00126	60	15/64	0.2344	0.0442	
	0.041	0.00132	59	1/4	0.250	0.0491	
	0.042	0.00138	58	17/64	0.2656	0.0554	
	0.043	0.00145	57	9/32	0.2812	0.0621	
	0.0465	0.00170	56	19/64	0.2969	0.0692	
3/64	0.0469	0.00173		5/16	0.3125	0.0767	
	0.0520	0.0021	55	21/64	0.3281	0.0845	
	0.0550	0.0023	54	11/32	0.3437	0.0928	
	0.0595	0.0028	53	23/64	0.3594	0.1014	
1/16	0.0625	0.0031		3/8	0.375	0.1104	
	0.0635	0.0032	52	25/64	0.3906	0.1198	
	0.0670	0.0035	51	13/32	0.4062	0.1296	
	0.070	0.0038	50	27/64	0.4219	0.1398	
	0.0730	0.0042	49	7/16	0.4375	0.1503	
	0.076	0.0043	48	29/64	0.4531	0.1612	
5/64	0.0781	0.0048		15/32	0.4687	0.1725	
	0.0785	0.0048	47	31/64	0.4844	0.1843	
	0.081	0.0051	46	1/2	0.500	0.1963	
	0.082	0.0053	45	33/64	0.5156	0.2088	
	0.086	0.0058	44	17/32	0.5312	0.2216	
	0.089	0.0062	43	35/64	0.5469	0.2349	
	0.0935	0.0069	42	9/16	0.5625	0.2485	
3/32	0.0937	0.0069		37/64	0.5781	0.2625	
	0.096	0.0072	41	19/32	0.5937	0.2769	
	0.098	0.0075	40	39/64	0.6094	0.2917	
	0.0995	0.0078	39	5/8	0.625	0.3068	
	0.1015	0.0081	38	41/64	0.6406	0.3223	
	0.104	0.0085	37	21/32	0.6562	0.3382	
	0.1065	0.0090	36	43/64	0.6719	0.3546	
7/64	0.1093	0.0094		11/16	0.6875	0.3712	
	0.110	0.0095	35	45/64	0.7031	0.3883	
	0.111	0.0097	34	23/32	0.7187	0.4057	
	0.113	0.0100	33	47/64	0.7344	0.4236	
	0.116	0.0106	32	3/4	0.750	0.4418	
	0.120	0.0113	31	49/64	0.7656	0.4604	
1/8	0.125	0.0123		25/32	0.7812	0.4794	
	0.1285	0.0130	30	51/64	0.7969	0.4988	
	0.136	0.0145	29	13/16	0.8125	0.5185	
	0.1405	0.0155	28	53/64	0.8281	0.5386	
9/64	0.1406	0.0155		27/32	0.8438	0.5591	
	0.144	0.0163	27	55/64	0.8594	0.5801	
	0.147	0.0174	26	7/8	0.875	0.6013	
	0.1495	0.0175	25	57/64	0.8906	0.6229	
	0.152	0.0181	24	29/32	0.9062	0.6450	
	0.154	0.0186	23	59/64	0.9219	0.6675	
5/32	0.156	0.0192		15/16	0.9375	0.6903	
	0.157	0.0193	22	61/64	0.9531	0.7134	
	0.159	0.0198	21	31/32	0.9687	0.7371	
	0.161	0.0203	20	63/64	0.9844	0.7610	
	0.166	0.0216	19	1	1.0000	0.7854	

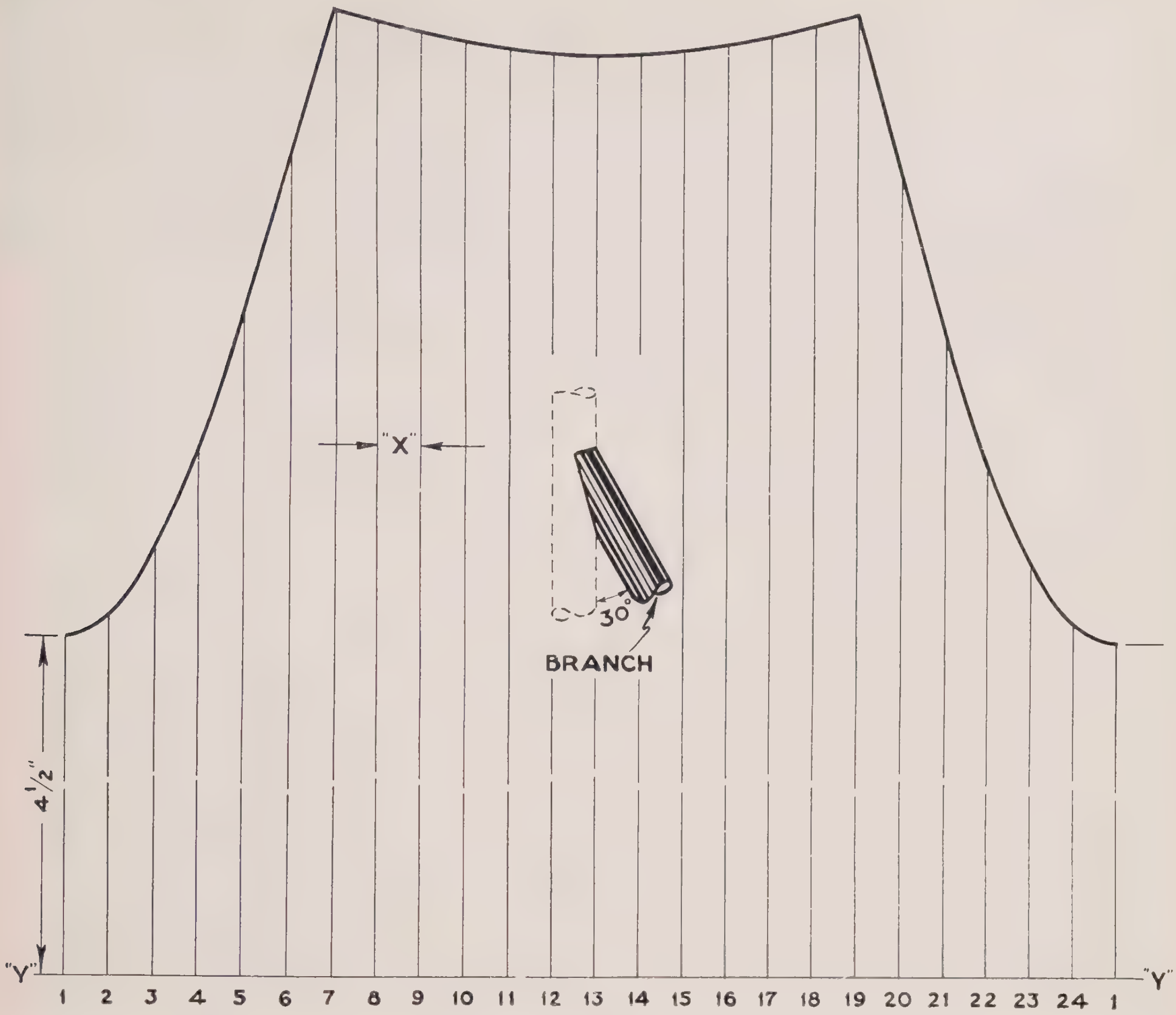
Templets for Cutting Pipe for Branches

In Lesson No. 6 tables and drawings were given for cutting pipe from 2½ inches to 36 inches in diameter to enable the welder to make accurate angle bends in the line. Templets for branches from a main line pipe, however, were not given for diameters above 2 inches and are set forth herewith. The manner in which the angular tem-



Size Pipe Inches	Outside Diam. Inches	Dist. X Inches	Length Base Line Y-Y Inches	Length of Ordinates for 30° Branch (Inches)												
				1, 2, 3, 4, 5, 6, 7, 19, 20, 21, 22, 23, 24	8, 18	9, 17	10, 16	11, 15	12, 14	13	A, L	B, K	C, J	D, H	E, G	F
2½	2.875	.3763	9.032	NOTE—These Ordinates Are Equal to Ordinate No. 13 Plus Ordinate No. F Plus 2 Inches.	1.35	2.64	3.75	4.62	5.18	5.35	.12	.19	.29	.34	.38	.40
3	3.500	.4582	10.996		1.66	3.24	4.61	5.64	6.26	6.52	.12	.24	.34	.41	.46	.48
3½	4.000	.5236	12.566		1.91	3.71	5.25	6.44	7.16	7.43	.12	.24	.34	.41	.46	.48
4	4.500	.5889	14.137		2.13	4.12	5.90	7.22	8.05	8.36	.16	.31	.44	.52	.59	.61
4½	5.000	.6545	15.708		2.41	4.64	6.54	8.04	8.98	9.31	.18	.34	.48	.59	.66	.67
5	5.563	.7282	17.477		2.70	5.24	7.38	9.00	10.03	10.40	.19	.37	.54	.65	.74	.76
6	6.625	.8672	20.813		3.16	6.18	8.69	10.69	11.92	12.37	.24	.46	.65	.81	.90	.92
7	7.625	.9981	23.955		3.78	7.17	10.12	12.33	13.76	14.26	.25	.49	.68	.86	.96	1.00
8	8.625	1.129	27.096		4.15	8.00	11.34	13.89	15.50	16.06	.29	.56	.80	.97	1.08	1.12
9	9.625	1.2599	30.238		4.72	8.98	12.69	15.55	17.33	17.94	.34	.65	.92	1.13	1.25	1.30
10	10.750	1.4072	33.772		4.98	9.91	14.04	17.22	19.20	19.91	.39	.77	1.10	1.35	1.49	1.54
11	11.750	1.538	36.914		5.72	10.94	15.44	18.93	21.14	21.85	.40	.78	1.11	1.36	1.50	1.55
12	12.750	1.6689	40.055		6.05	11.86	16.71	20.56	22.92	23.72	.46	.87	1.23	1.50	1.67	1.72
14	14.000	1.8325	43.982		6.76	12.90	18.40	22.58	25.20	26.16	.48	.90	1.26	1.52	1.68	1.73
15	15.000	1.9635	47.124		6.90	13.66	19.66	24.04	26.90	27.86	.49	1.03	1.48	1.80	2.00	2.10
16	16.000	2.0944	50.265		7.74	14.94	21.16	25.82	28.78	29.84	.56	1.04	1.45	1.82	2.02	2.08
18	18.000	2.3562	56.548		8.82	17.00	23.94	29.26	32.58	33.72	.60	1.16	1.64	2.00	2.26	2.34
20	20.000	2.618	62.832		9.86	18.86	26.58	32.52	36.16	37.44	.61	1.18	1.65	2.01	2.23	2.32
24	24.000	3.1415	75.398		11.94	22.56	31.86	38.80	43.34	44.80	.78	1.49	2.10	2.55	2.84	2.95
30	30.000	3.927	94.248		13.80	27.32	39.32	48.08	53.80	55.72	.98	2.06	2.96	3.60	4.00	4.20
36	36.000	4.7125	113.100		17.64	34.00	47.88	58.52	65.16	67.44	1.20	2.32	3.28	4.00	4.52	4.68

These Templets Are Used on the Run



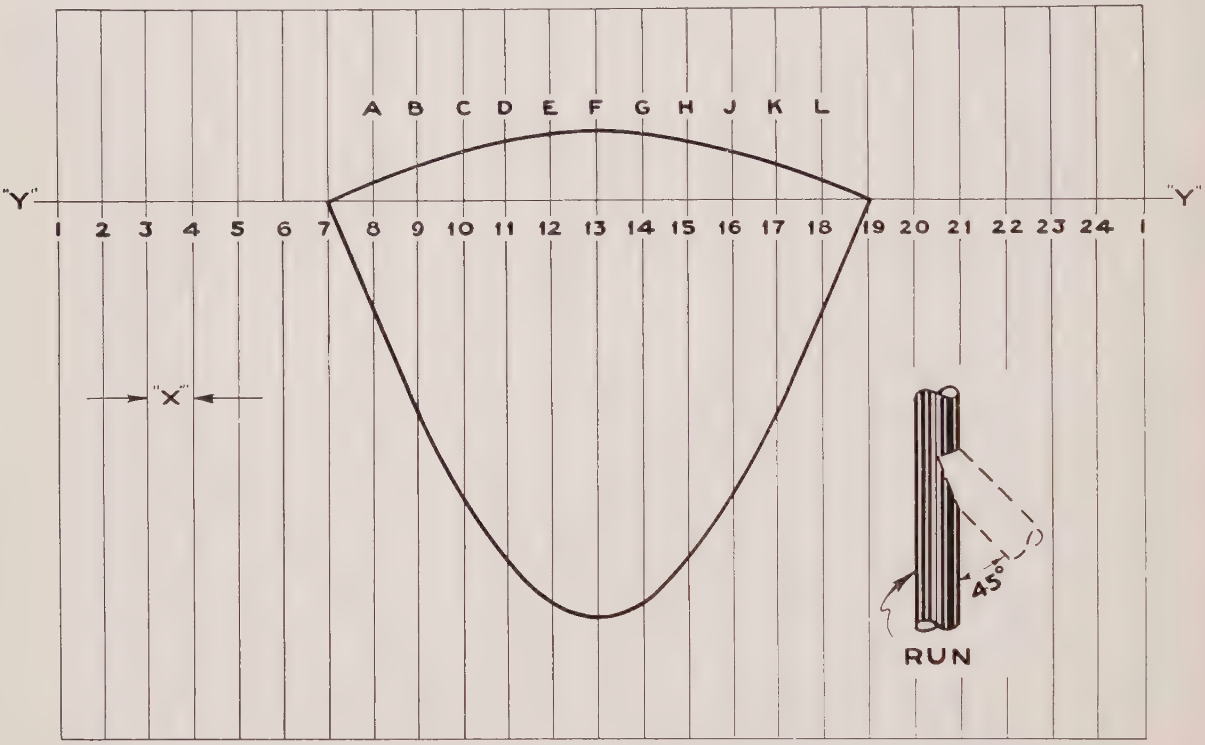
Size Pipe Inches	Length of Ordinates for 30° Branch (Inches)											
	1	**2, 24**	**3, 23**	**4, 22**	**5, 21**	**6, 20**	**7, 19**	**8, 18**	**9, 17**	**10, 16**	**11, 15**	**12, 14**	**13**
2½	4.50	4.68	5.23	6.10	7.22	8.50	9.87	9.78	9.68	9.60	9.54	9.50	9.48
3	4.50	4.75	5.38	6.41	7.78	9.35	11.01	10.90	10.78	10.69	10.61	10.56	10.55
3½	4.50	4.77	5.48	6.68	8.21	10.00	11.90	11.76	11.61	11.49	11.39	11.33	11.31
4	4.50	4.82	5.64	6.95	8.72	10.70	12.85	12.69	12.54	12.41	12.33	12.26	12.24
4½	4.50	4.83	5.75	7.26	9.17	11.39	13.82	13.64	13.48	13.34	13.23	13.17	13.14
5	4.50	4.88	5.90	7.52	9.65	12.20	14.89	14.72	14.54	14.39	14.27	14.19	14.16
6	4.50	4.96	6.18	8.19	10.70	13.70	16.88	16.62	16.41	16.25	16.10	16.01	15.98
7	4.50	5.00	6.42	8.74	11.62	15.00	18.79	18.49	18.25	18.00	17.87	17.76	17.73
8	4.50	5.05	6.68	9.23	12.58	16.43	20.61	20.30	20.01	19.78	19.60	19.48	19.43
9	4.50	5.10	6.89	9.75	13.45	17.70	22.42	22.07	21.77	21.50	21.30	21.17	21.14
10	4.50	5.22	7.20	10.40	14.55	19.44	24.44	24.10	23.77	23.48	23.27	23.14	23.10
11	4.50	5.23	7.42	10.91	15.40	20.63	26.33	25.93	25.55	25.22	24.97	24.81	24.76
12	4.50	5.32	7.68	11.55	16.42	22.23	28.30	27.87	27.45	27.10	26.81	26.64	26.57
14	4.50	5.40	8.04	12.24	17.74	23.86	30.64	30.10	29.62	29.18	28.84	28.64	28.58
15	4.50	5.46	8.28	12.66	18.66	25.42	32.30	31.84	31.40	30.96	30.66	30.44	30.40
16	4.50	5.58	8.52	13.20	19.40	26.60	34.36	33.80	33.26	32.80	32.42	32.20	32.10
18	4.50	5.60	8.92	14.24	21.20	29.38	38.18	37.54	36.94	36.42	36.04	35.78	35.70
20	4.50	5.78	9.46	15.36	23.06	32.08	41.94	41.16	40.46	39.82	39.34	39.02	38.94
24	4.50	6.00	10.52	17.48	26.76	37.44	49.36	48.48	47.64	46.92	46.36	46.04	45.90
30	4.50	6.42	12.06	20.82	32.82	46.34	60.10	59.18	58.30	57.42	56.82	56.38	56.30
36	4.50	6.70	13.34	23.98	37.90	54.26	71.86	70.58	69.38	68.34	67.58	67.06	66.90

These Templets Are Used on the Branch

plets were made was fully described on page 66 and the method for making a Y-branch templet was described on page 68.

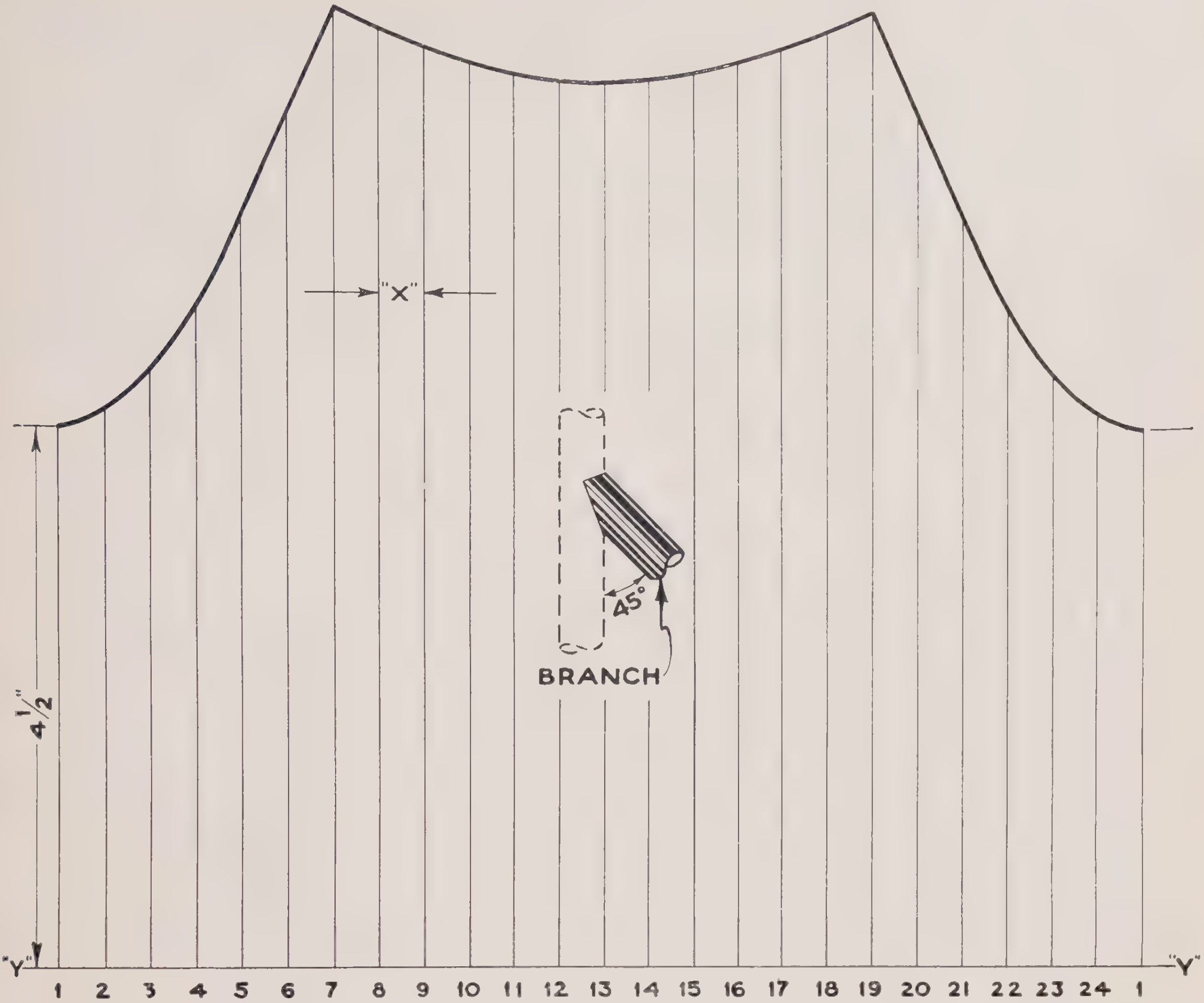
There must be two templets used to cut pipe for a branch, one of these being a templet which will locate and outline the hole which is cut in the main line pipe. This pipe is called the run and the pipe extending from it the branch. The second templet is used to cut the end of the branch pipe, so that it will closely fit the hole cut in the main line. It will be appreciated that the hole in the main line must be centered and so located that it is in correct alignment with the pipe. It would be possible to make a templet for the hole in the pipe which would only outline the hole, but in this case it would be difficult for the welder to place this templet on the pipe so that it would be in the correct position.

The ordinates used to establish the line of cut at the end of the branch pipe extend only one way



Size Pipe Inch-es	Out-side Diam. Inches	Dist. X Inches	Length Base Line Y-Y Inches	Length of Ordinates for 45° Branch (Inches)												
				1, 2, 3, 4, 5, 6, 7, 19, 20, 21, 22, 23, 24	8, 18	9, 17	10, 16	11, 15	12, 14	13	A, L	B, K	C, J	D, H	E, G	F
2½	2.875	.3763	9.032	NOTE—These Ordinates Are Equal to Ordinate No. 13 Plus Ordinate No. F Plus 2 Inches.	.92	1.75	2.46	2.98	3.34	3.47	.14	.29	.41	.50	.56	.59
3	3.500	.4582	10.996		1.09	2.12	2.98	3.65	4.08	4.22	.17	.35	.49	.61	.69	.72
3½	4.000	.5236	12.566		1.26	2.41	3.40	4.16	4.63	4.80	.20	.40	.57	.71	.79	.82
4	4.500	.5889	14.137		1.36	2.72	3.84	4.69	5.24	5.42	.23	.47	.65	.79	.89	.92
4½	5.000	.6545	15.708		1.56	3.00	4.26	5.23	5.83	6.03	.27	.52	.72	.89	1.00	1.04
5	5.563	.7282	17.477		1.76	3.37	4.77	5.82	6.48	6.72	.30	.57	.81	.98	1.10	1.14
6	6.625	.8672	20.813		2.07	3.98	5.62	6.89	7.68	7.98	.36	.68	.96	1.18	1.34	1.38
7	7.625	.9981	23.955		2.46	4.68	6.55	7.98	8.89	9.20	.41	.80	1.10	1.35	1.50	1.56
8	8.625	1.129	27.096		2.68	5.19	7.32	8.98	10.04	10.41	.45	.87	1.24	1.53	1.72	1.79
9	9.625	1.2599	30.238		2.97	5.80	8.17	10.05	11.20	11.60	.50	1.00	1.41	1.74	1.93	2.00
10	10.750	1.4072	33.772		3.36	6.47	9.18	11.25	12.48	12.90	.58	1.12	1.58	1.95	2.17	2.23
11	11.750	1.538	36.914		3.68	7.08	10.02	12.23	13.62	14.12	.62	1.22	1.71	2.10	2.35	2.43
12	12.750	1.6689	40.055		4.09	7.75	10.90	13.33	14.84	15.40	.69	1.31	1.85	2.25	2.52	2.61
14	14.000	1.8325	43.982		4.34	8.41	11.92	14.65	16.32	16.95	.72	1.46	2.03	2.51	2.79	2.90
15	15.000	1.9635	47.124		4.64	8.95	12.72	15.62	17.45	18.07	.78	1.55	2.18	2.70	3.00	3.09
16	16.000	2.0944	50.265		4.98	9.61	13.55	16.71	18.62	19.25	.85	1.69	2.40	2.92	3.25	3.36
18	18.000	2.3562	56.548		5.61	10.88	15.41	18.85	21.03	21.75	.96	1.85	2.63	3.25	3.62	3.75
20	20.000	2.618	62.832		6.30	12.11	17.14	20.95	23.32	24.08	1.09	2.08	2.95	3.60	4.04	4.18
24	24.000	3.1415	75.398		7.50	14.44	20.42	25.00	27.83	28.90	1.30	2.52	3.58	4.38	4.90	5.07
30	30.000	3.927	94.248		9.28	17.90	25.44	31.24	34.90	36.14	1.56	3.10	4.36	5.40	6.00	6.18
36	36.000	4.7125	113.100		11.22	21.76	30.82	37.70	42.06	43.50	1.92	3.70	5.26	6.50	7.24	7.50

These Templets Are Used on the Run



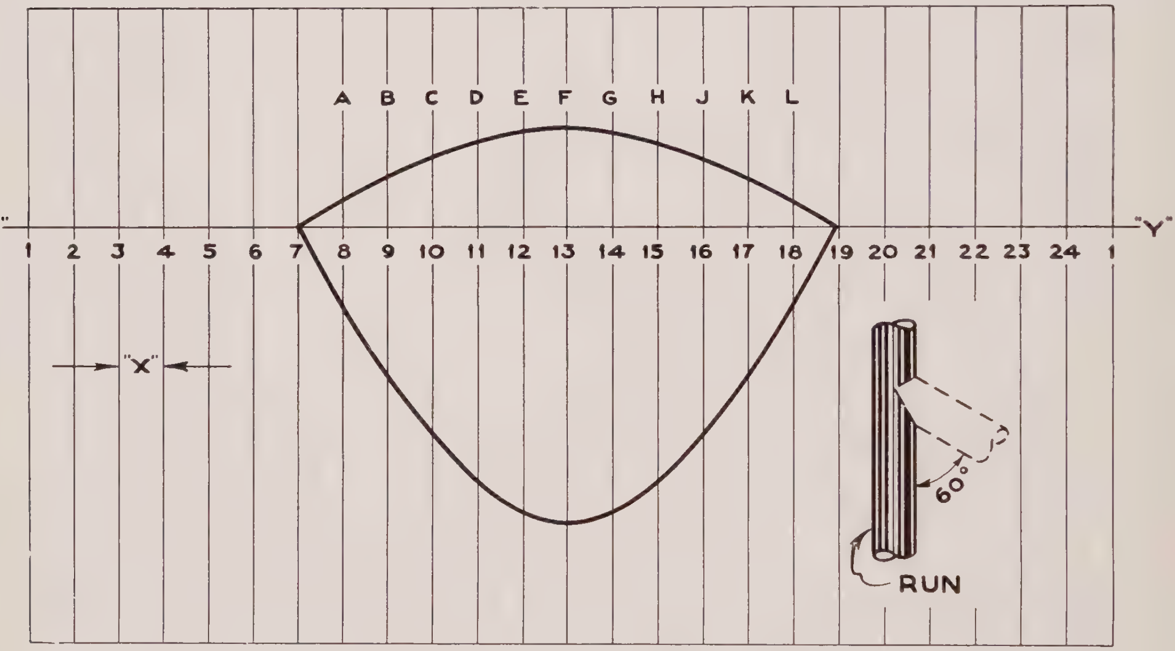
Size Pipe Inches	Length of Ordinates for 45° Branch (Inches)												
	1	**2, 24**	**3, 23**	**4, 22**	**5, 21**	**6, 20**	**7, 19**	**8, 18**	**9, 17**	**10, 16**	**11, 15**	**12, 14**	**13**
2½	4.50	4.64	4.98	5.51	6.23	7.08	7.98	7.83	7.68	7.56	7.47	7.41	7.39
3	4.50	4.65	5.05	5.73	6.59	7.62	8.70	8.51	8.35	8.18	8.08	8.01	7.98
3½	4.50	4.66	5.15	5.91	6.89	8.04	9.31	9.09	8.89	8.72	8.59	8.51	8.48
4	4.50	4.67	5.24	6.09	7.19	8.55	9.91	9.67	9.45	9.26	9.11	9.01	8.98
4½	4.50	4.70	5.30	6.26	7.52	8.96	10.52	10.26	10.00	9.79	9.64	9.53	9.50
5	4.50	4.73	5.38	6.44	7.83	9.44	11.20	10.90	10.62	10.37	10.19	10.08	10.04
6	4.50	4.79	5.58	6.84	8.49	10.39	12.48	12.12	11.79	11.51	11.29	11.16	11.11
7	4.50	4.82	5.73	7.15	9.00	11.21	13.69	13.26	12.88	12.56	12.32	12.17	12.10
8	4.50	4.88	5.92	7.59	9.71	12.22	14.90	14.45	14.02	13.65	13.37	13.19	13.12
9	4.50	4.90	6.06	7.93	10.30	13.14	16.13	15.60	15.12	14.72	14.40	14.21	14.15
10	4.50	4.92	6.15	8.25	10.92	14.05	17.40	16.82	16.30	15.84	15.49	15.26	15.20
11	4.50	5.00	6.35	8.61	11.55	14.95	18.62	18.00	17.40	16.89	16.52	16.30	16.21
12	4.50	5.04	6.54	9.00	12.15	15.82	19.91	19.20	18.56	18.00	17.59	17.31	17.22
14	4.50	5.08	6.80	9.52	13.04	17.09	21.42	20.68	19.98	19.39	18.91	18.64	18.53
15	4.50	5.11	6.89	9.83	13.59	17.91	22.55	21.76	21.00	20.38	19.89	19.56	19.45
16	4.50	5.15	7.05	10.18	14.12	18.78	23.76	22.91	22.12	21.45	20.92	20.59	20.51
18	4.50	5.20	7.39	10.82	15.38	20.62	26.22	25.28	24.37	23.60	23.00	22.64	22.50
20	4.50	5.30	7.65	11.48	16.50	22.30	28.60	27.51	26.54	25.68	25.03	24.62	24.49
24	4.50	5.57	8.38	12.97	18.95	25.87	33.36	32.09	30.92	29.90	29.13	28.65	28.50
30	4.50	5.72	9.28	15.16	22.68	31.32	40.60	39.02	37.50	36.26	35.28	34.62	34.40
36	4.50	5.90	10.28	17.14	26.26	36.74	47.94	46.06	44.24	42.70	41.50	40.78	40.50

These Templets Are Used on the Branch

from the base line, Y-Y, but those used for cutting the hole in the run must extend both ways from the base line, as shown in all of the run templets with the exception of the Y-branch. The method of laying out a templet is quite simple and is fully covered on pages Nos. 97 and 98. The run templet, however, differs somewhat from this description and is set forth as follows:

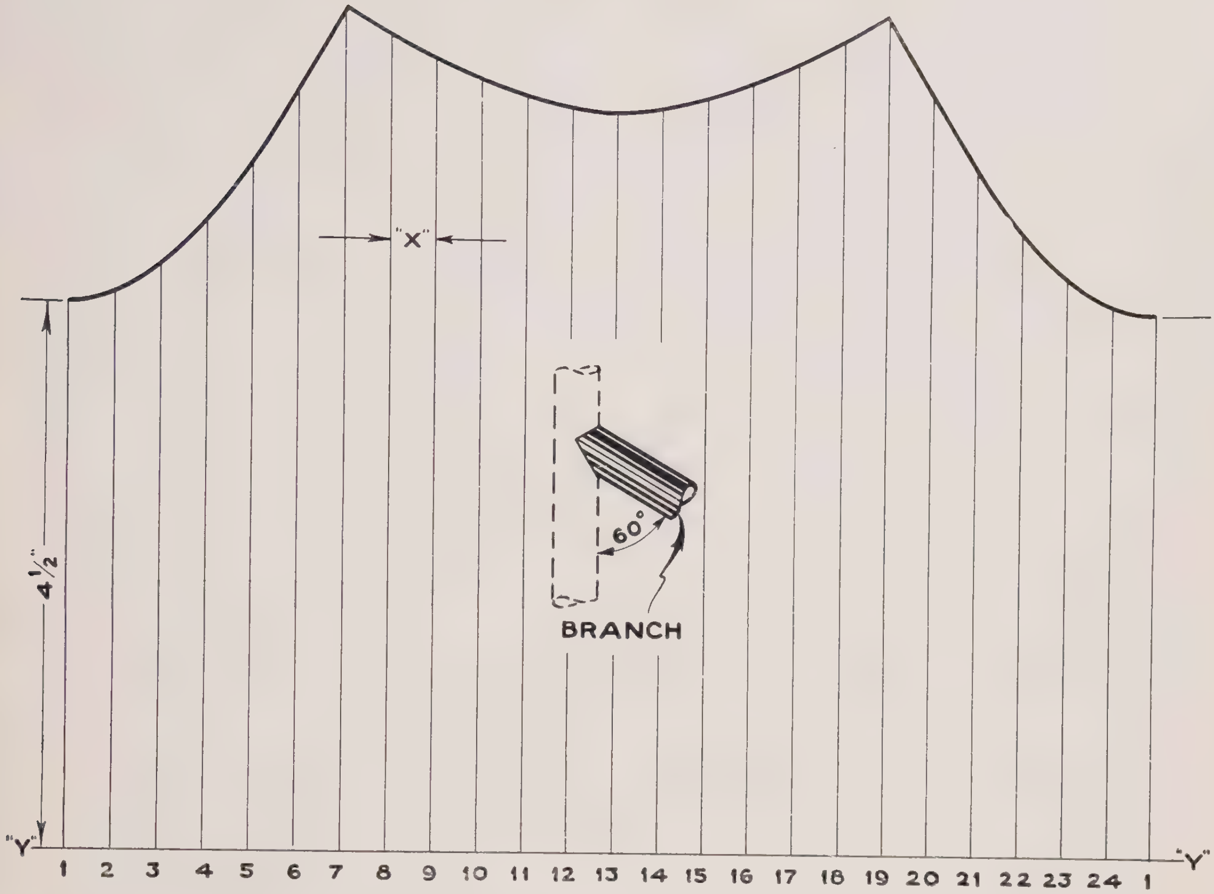
As an example, the reader is referred to the templet for the run of a 30-degree branch, illustrated upon page 344. The base line, Y-Y, should be laid out, a straight, horizontal line across a sheet of paper of suitable size. The length of this line is given in the column headed "Length, Base Line, Y-Y, Inches." If, for instance, the diameter of the pipe, for which the templet is to be made is ten inches, the length of the base line, Y-Y, as shown in the table, is 33.772 inches. Reference to the table, "Fractions to Decimals," on page 95, will enable the transposition of the decimal .772 to the nearest fraction of an inch if desired. The base line, Y-Y, is then divided into twenty-four spaces, each space being as given in the column headed "Distance X Inches," opposite ten inch pipe.

The base line is as long as the outside circumference and will extend clear around the pipe. The object in making this templet so large and of



Size Pipe Inches	Outside Diam. Inches	Dist. X Inches	Length Base Line Y-Y Inches	Length of Ordinates for 60° Branch (Inches)												
				1, 2, 3, 4, 5, 6, 7, 19, 20, 21, 22, 23, 24	8, 18	9, 17	10, 16	11, 15	12, 14	13	A, L	B, K	C, J	D, H	E, G	F
2½	2.875	.3763	9.032	NOTE—These Ordinates Are Equal to Ordinate No. 13 Plus Ordinate No. F Plus 2 Inches.	.64	1.25	1.75	2.13	2.38	2.46	.20	.41	.58	.72	.80	.83
3	3.500	.4582	10.996		.79	1.51	2.15	2.62	2.91	3.00	.25	.48	.70	.86	.97	1.00
3½	4.000	.5236	12.566		.84	1.68	2.42	2.97	3.31	3.45	.29	.57	.81	1.00	1.12	1.15
4	4.500	.5889	14.137		1.00	1.92	2.73	3.36	3.72	3.87	.34	.66	.93	1.14	1.27	1.32
4½	5.000	.6545	15.708		1.13	2.17	3.06	3.77	4.19	4.34	.36	.70	1.00	1.24	1.39	1.43
5	5.563	.7282	17.477		1.25	2.41	3.40	4.17	4.64	4.80	.42	.82	1.15	1.40	1.55	1.61
6	6.625	.8672	20.813		1.45	2.86	4.03	4.95	5.50	5.73	.51	.97	1.35	1.67	1.85	1.93
7	7.625	.9981	23.955		1.72	3.34	4.70	5.75	6.38	6.60	.56	1.10	1.55	1.90	2.12	2.20
8	8.625	1.129	27.096		1.97	3.75	5.25	6.43	7.18	7.43	.65	1.25	1.75	2.15	2.41	2.50
9	9.625	1.2599	30.238		2.15	4.15	5.88	7.20	8.03	8.28	.71	1.40	1.96	2.40	2.70	2.78
10	10.750	1.4072	33.772		2.57	4.98	7.04	8.61	9.59	9.92	.85	1.65	2.35	2.88	3.20	3.32
11	11.750	1.538	36.914		2.65	5.09	7.17	8.77	9.75	10.10	.88	1.71	2.40	2.95	3.29	3.40
12	12.750	1.6689	40.055		2.78	5.45	7.74	9.50	10.58	11.00	.93	1.83	2.58	3.17	3.53	3.68
14	14.000	1.8325	43.982		3.10	6.05	8.48	10.39	11.62	12.05	1.00	2.02	2.85	3.50	3.88	4.05
15	15.000	1.9635	47.124		3.32	6.47	9.10	11.15	12.48	12.91	1.11	2.17	3.05	3.75	4.19	4.32
16	16.000	2.0944	50.265		3.64	6.94	9.83	12.03	13.35	13.83	1.21	2.31	3.29	4.03	4.46	4.63
18	18.000	2.3562	56.548		4.05	7.82	11.01	13.50	15.03	15.58	1.35	2.62	3.70	4.50	5.02	5.20
20	20.000	2.618	62.832		4.53	8.72	12.10	14.90	16.60	17.25	1.50	2.90	4.05	5.00	5.59	5.80
24	24.000	3.1415	75.398		5.39	10.40	14.75	18.05	20.13	20.83	1.79	3.42	4.83	5.93	6.62	6.89
30	30.000	3.927	94.248		6.64	12.94	18.20	22.30	24.96	25.82	2 22	4.34	6.10	7.50	8.38	8.64
36	36.000	4.7125	113.100		8.10	15.64	22.02	27.00	30.06	31.16	2.70	5.24	7.40	9.00	10.04	10.40

These Templets Are Used on the Run



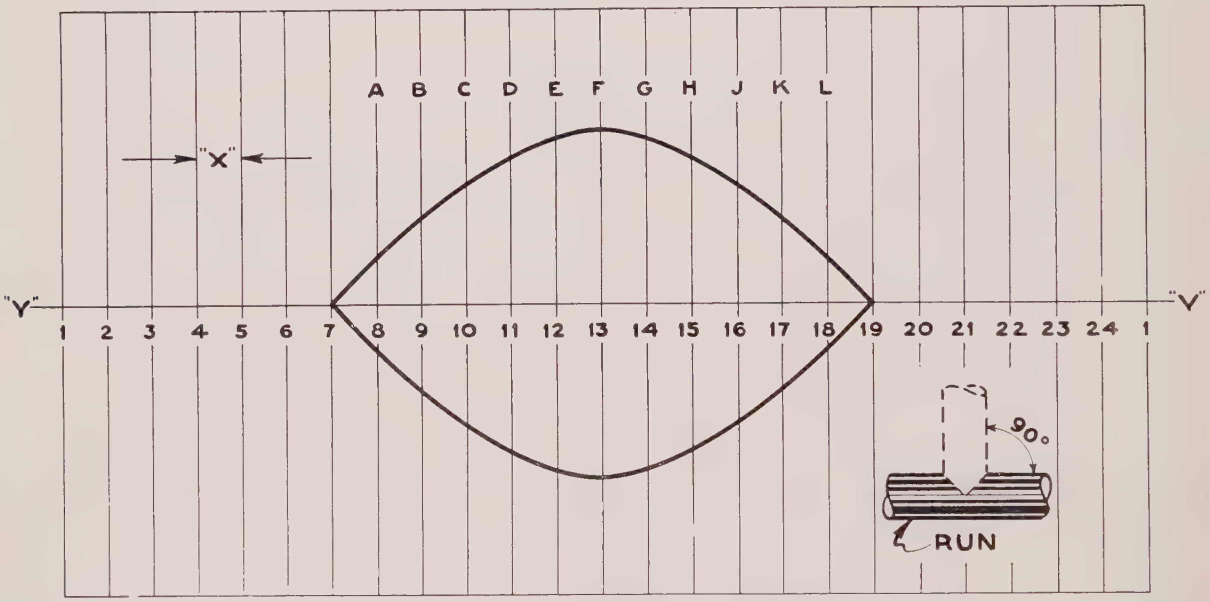
Size Pipe Inches	Length of Ordinates for 60° Branch (Inches)												
	1	2, 24	3, 23	4, 22	5, 21	6, 20	7, 19	8, 18	9, 17	10, 16	11, 15	12, 14	13
2½	4.50	4.58	4.84	5.20	5.71	6.32	6.96	6.75	6.55	6.39	6.26	6.17	6.14
3	4.50	4.60	4.90	5.36	6.00	6.72	7.51	7.25	7.00	6.80	6.64	6.55	6.50
3½	4.50	4.63	4.97	5.52	6.25	7.09	7.95	7.66	7.37	7.13	6.95	6.83	6.79
4	4.50	4.65	5.00	5.64	6.45	7.38	8.39	8.05	7.73	7.46	7.25	7.14	7.08
4½	4.50	4.67	5.07	5.76	6.66	7.69	8.81	8.45	8.10	7.80	7.56	7.43	7.36
5	4.50	4.67	5.14	5.90	6.90	8.06	9.32	8.91	8.52	8.18	7.92	7.77	7.71
6	4.50	4.71	5.25	6.18	7.34	8.75	10.23	9.74	9.27	8.88	8.57	8.38	8.32
7	4.50	4.73	5.34	6.40	7.75	9.36	11.08	10.50	9.97	9.53	9.18	8.96	8.90
8	4.50	4.75	5.50	6.68	8.20	9.97	11.95	11.30	10.70	10.18	9.80	9.55	9.45
9	4.50	4.76	5.60	6.92	8.64	10.65	12.80	12.10	11.42	10.85	10.40	10.12	10.04
10	4.50	4.83	5.82	7.40	9.45	11.87	14.43	13.59	12.77	12.09	11.56	11.24	11.12
11	4.50	4.85	5.85	7.45	9.54	12.00	14.63	13.75	12.95	12.25	11.70	11.37	11.25
12	4.50	4.90	6.00	7.75	10.04	12.71	15.50	14.56	13.67	12.92	12.34	11.96	11.84
14	4.50	4.92	6.12	8.05	10.50	13.45	16.55	15.52	14.53	13.71	13.09	12.65	12.52
15	4.50	4.95	6.25	8.25	10.92	14.07	17.42	16.30	15.25	14.38	13.70	13.25	13.08
16	4.50	5.00	6.30	8.52	11.40	14.73	18.33	17.15	16.05	15.08	14.35	13.90	13.74
18	4.50	5.06	6.58	9.05	12.25	16.00	20.05	18.74	17.48	16.43	15.58	15.10	14.90
20	4.50	5.16	6.86	9.64	13.05	17.23	21.77	20.27	18.88	17.75	16.80	16.23	16.01
24	4.50	5.20	7.30	10.60	14.93	19.95	25.35	23.54	21.87	20.41	19.28	18.60	18.35
30	4.50	5.40	8.00	12.00	17.34	23.64	30.34	28.10	26.00	24.26	22.90	22.00	21.66
36	4.50	5.62	8.66	13.60	20.00	27.50	35.60	32.98	30.46	28.36	26.66	25.70	25.30

These Templets Are Used on the Branch

rectangular shape is to make one which will wrap completely around the outside of the pipe and thus center the hole which is to be cut. Through each one of the division points in the base line, Y-Y, right angle ordinates are drawn and numbered as shown in the sketch on page 344. It will be noted by consulting the tables that ordinates numbers 1, 2, 3, 4, 5, 6, 7, 19, 20, 21, 22, 23, 24 and 1 are exactly alike and are equal to ordinate No. 13 plus ordinate No. F plus two inches. No. 13, for ten inch pipe, is equal to 19.91 inches. Ordinate No. F is equal to 1.54 inches and the sum of these two added to two inches gives a total of 23.45 inches, the total length of the templet. The distance 19.91 inches, which is ordinate No. 13, plus one inch, should be laid off on ordinates No. 1 from each end of the base line, Y-Y, to the lower corners of the templet, as shown on the page.

The distance 1.54 inches, which is the ordinate F plus one inch, or 2.54 inches, should be laid off on ordinates Nos. 1 at each end of the base line, Y-Y, to give the two upper corners of the templet. This will make a rectangle, representing the entire templet, and it will be large enough to wrap entirely around the pipe.

It then is necessary to lay off ordinates Nos. 8 and 18; 9 and 17; 10 and 16, etc., of the lengths given in the tables for ten inch pipe, below the base line, Y-Y, to establish points in the curve shown. In like manner ordinates A and L; B and K; C and J, etc., are laid out above the base line to establish the end or upper curve of the

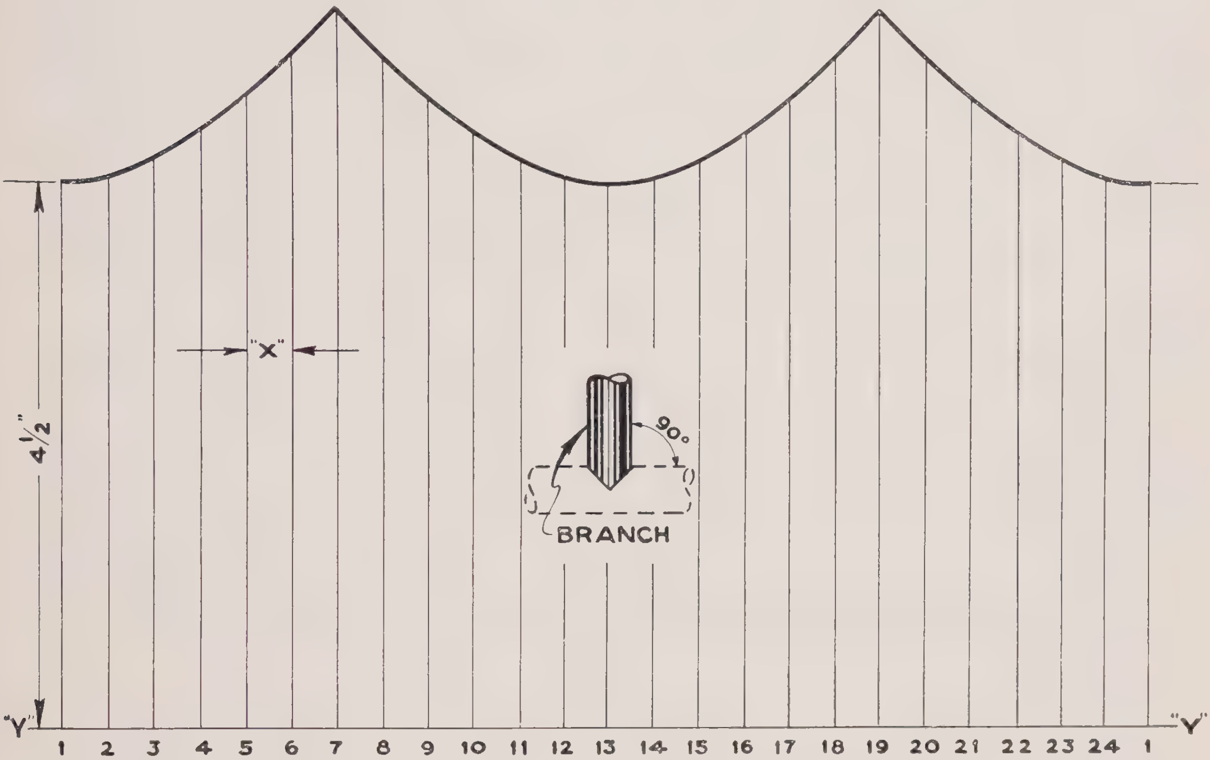


Size Pipe Inches	Outside Diam. Inches	Dist. X Inches	Length Base Line Y-Y Inches	Length of Ordinates for 90° Branch (Inches)						
				1, 2, 3, 4, 5, 6, 7, 19, 20, 21, 22, 23, 24	8, 18, A, L	9, 17, B, K	10, 16, C, J	11, 15, D, H	12, 14, E, G	13, F
2½	2.875	.3763	9.032	NOTE—These Ordinates Are Equal to Ordinate No. 13 Plus Ordinate No. F Plus 2 Inches.	.37	.72	1.01	1.24	1.38	1.44
3	3.500	.4582	10.996		.46	.87	1.25	1.52	1.67	1.75
3½	4.000	.5236	12.566		.52	1.00	1.42	1.72	1.93	2.00
4	4.500	.5889	14.137		.56	1.11	1.57	1.94	2.15	2.25
4½	5.000	.6545	15.708		.60	1.22	1.75	2.15	2.39	2.50
5	5.563	.7282	17.477		.73	1.40	1.97	2.40	2.67	2.78
6	6.625	.8672	20.813		.86	1.66	2.35	2.87	3.20	3.31
7	7.625	.9981	23.955		1.01	1.92	2.71	3.30	3.67	3.81
8	8.625	1.129	27.096		1.10	2.15	3.05	3.75	4.17	4.31
9	9.625	1.2599	30.238		1.23	2.40	3.42	4.16	4.65	4.81
10	10.750	1.4072	33.772		1.37	2.69	3.80	4.65	5.19	5.37
11	11.750	1.538	36.914		1.52	2.92	4.15	5.08	5.67	5.87
12	12.750	1.6689	40.055		1.67	3.19	4.51	5.52	6.15	6.37
14	14.000	1.8325	43.982		1.81	3.53	4.98	6.11	6.78	7.00
15	15.000	1.9635	47.124		1.96	3.75	5.30	6.50	7.25	7.50
16	16.000	2.0944	50.265		2.07	4.00	5.70	6.94	7.72	8.00
18	18.000	2.3562	56.548		2.30	4.50	6.37	7.79	8.69	9.00
20	20.000	2.618	62.832		2.64	5.06	7.16	8.74	9.70	10.00
24	24.000	3.1415	75.398		3.08	6.00	8.50	10.42	11.61	12.00
30	30.000	3.927	94.248		3.92	7.50	10.60	13.00	14.50	15.00
36	36.000	4.7125	113.100		4.60	9.00	12.74	15.58	17.38	18.00

These Templets Are Used on the Run

templet outlining the hole in the run. The templet is then cut out along ordinates Nos. 1 and 1 on the two ends at the top and bottom as shown, and the hole is cut along the curved line. It can then be wrapped around the pipe, so that the ordinates, 1-1, meet on the opposite side of the pipe, to that in which the hole is to be cut and the hole will be centrally located and in line with the center line of the run.

Prick marks may be made with a center punch along the curved line of the opening, or the templet may be transferred to a sheet of brass to make a permanent templet in which the opening is completely cut out. Further explanation of

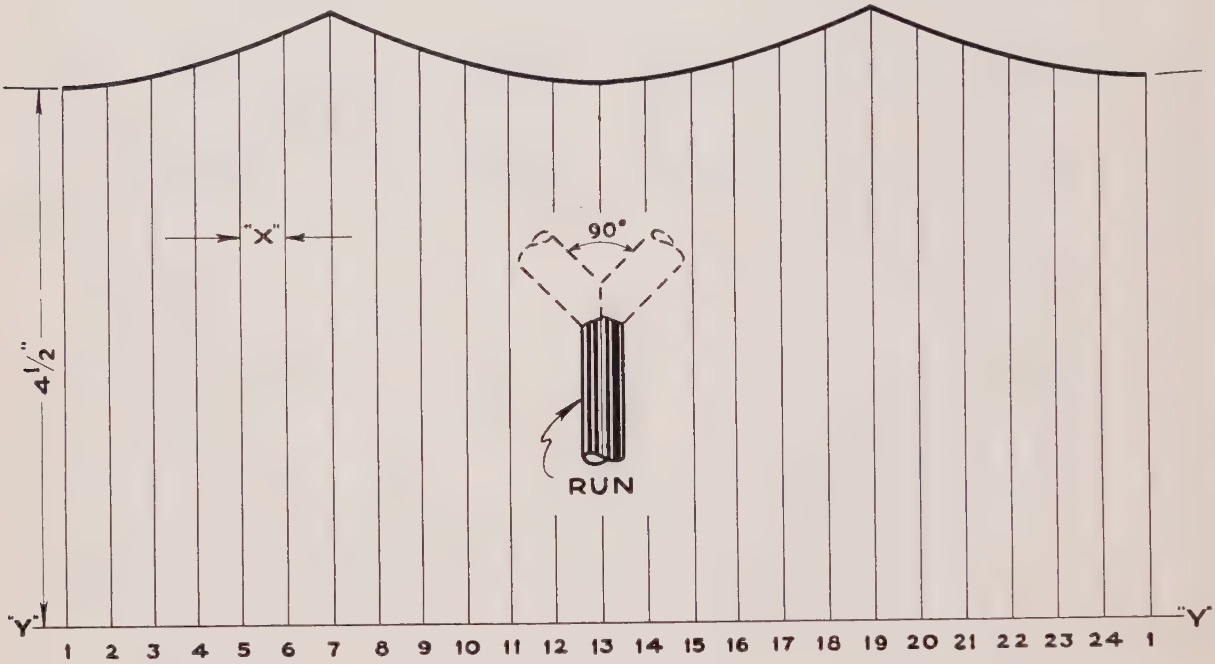


Size Pipe Inches	Length of Ordinates for 90° Branch (Inches)						
	1, 13	2, 24—12, 14	3, 23—11, 15	4, 22—10, 16	5, 21—9, 17	6, 20—8, 18	7, 19
2½	4.50	4.53	4.68	4.92	5.22	5.56	5.94
3	4.50	4.55	4.74	5.00	5.37	5.80	6.25
3½	4.50	4.56	4.77	5.08	5.49	5.97	6.49
4	4.50	4.58	4.80	5.17	5.63	6.18	6.75
4½	4.50	4.59	4.84	5.24	5.75	6.37	7.00
5	4.50	4.60	4.87	5.30	5.88	6.55	7.28
6	4.50	4.61	4.95	5.47	6.14	6.95	7.81
7	4.50	4.63	5.00	5.60	6.39	7.31	8.31
8	4.50	4.64	5.09	5.77	6.67	7.71	8.81
9	4.50	4.66	5.14	5.90	6.91	8.08	9.31
10	4.50	4.68	5.21	6.09	7.19	8.50	9.87
11	4.50	4.70	5.28	6.22	7.43	8.85	10.37
12	4.50	4.71	5.34	6.35	7.67	9.19	10.87
14	4.50	4.74	5.40	6.52	7.97	9.66	11.50
15	4.50	4.76	5.50	6.70	8.27	10.08	12.00
16	4.50	4.78	5.59	6.85	8.50	10.43	12.50
18	4.50	4.80	5.71	7.12	9.00	11.22	13.50
20	4.50	4.82	5.80	7.38	9.45	11.85	14.50
24	4.50	4.90	6.06	8.00	10.50	13.39	16.50
30	4.50	5.02	6.50	8.90	12.04	15.66	19.50
36	4.50	5.10	6.92	9.74	13.50	17.94	22.50

These Templets Are Used on the Branch

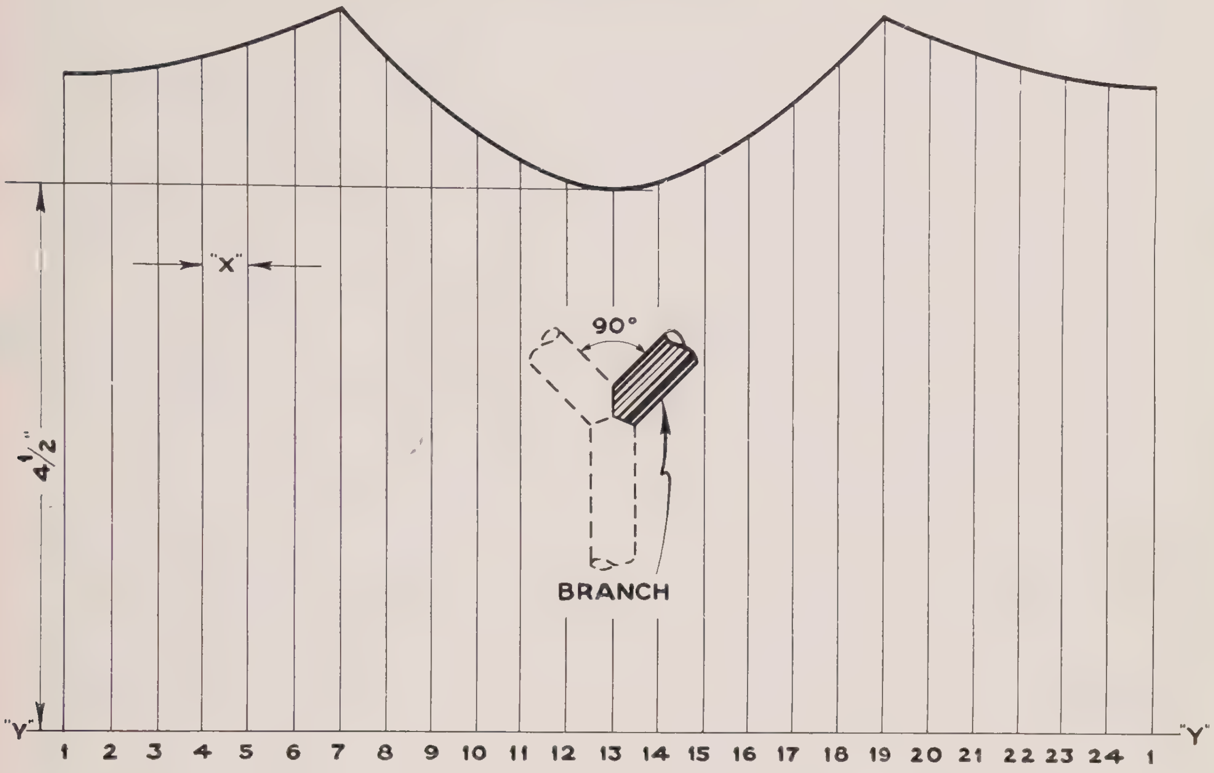
this method does not seem necessary in view of previous descriptions of templets in Lessons 5 and 6.

The templets for the branches do not require explanation because these are identical with those already described where the ends of the pipe only are to be cut.



Size Pipe Inches	Outside Diam. Inches	Dist. X Inches	Length Base Line Y-Y Inches	Length of Ordinates for "Y" Branch (Inches)						
				1, 13	2, 12—14, 24	3, 11—15, 23	4, 10—16, 22	5, 9—17, 21	6, 8—18, 20	7, 19
2½	2.875	.3763	9.032	4.50	4.51	4.58	4.67	4.80	4.95	5.11
3	3.500	.4582	10.996	4.50	4.52	4.60	4.72	4.87	5.03	5.22
3½	4.000	.5236	12.566	4.50	4.53	4.61	4.74	4.92	5.11	5.33
4	4.500	.5889	14.137	4.50	4.54	4.63	4.77	4.95	5.18	5.43
4½	5.000	.6545	15.708	4.50	4.54	4.64	4.80	5.02	5.25	5.54
5	5.563	.7282	17.477	4.50	4.54	4.66	4.85	5.09	5.38	5.67
6	6.625	.8672	20.813	4.50	4.55	4.68	4.90	5.18	5.52	5.86
7	7.625	.9981	23.955	4.50	4.55	4.70	4.95	5.30	5.67	6.07
8	8.625	1.129	27.096	4.50	4.56	4.74	5.00	5.37	5.81	6.28
9	9.625	1.2599	30.238	4.50	4.56	4.76	5.08	5.50	5.97	6.47
10	10.750	1.4072	33.772	4.50	4.58	4.79	5.17	5.62	6.16	6.74
11	11.750	1.538	36.914	4.50	4.58	4.82	5.19	5.68	6.27	6.90
12	12.750	1.6689	40.055	4.50	4.59	4.85	5.25	5.78	6.42	7.10
14	14.000	1.8325	43.982	4.50	4.60	4.88	5.32	5.90	6.60	7.36
15	15.000	1.9635	47.124	4.50	4.61	4.90	5.38	6.00	6.76	7.55
16	16.000	2.0944	50.265	4.50	4.62	4.95	5.46	6.14	6.90	7.78
18	18.000	2.3562	56.548	4.50	4.63	5.00	5.58	6.35	7.24	8.19
20	20.000	2.618	62.832	4.50	4.65	5.06	5.72	6.56	7.60	8.70
24	24.000	3.1415	75.398	4.50	4.68	5.18	6.00	7.04	8.24	9.56
30	30.000	3.927	94.248	4.50	4.72	5.30	6.26	7.50	9.02	10.60
36	36.000	4.7125	113.100	4.50	4.76	5.50	6.66	8.20	9.98	11.88

These Templets are Used on the Run



Size Pipe Inches	Outside Diam. Inches	Dist. X Inches	Length Base Line Y-Y Inches	Lengths of Ordinates for "Y" Branch (Inches)											
				1	2, 24	3, 23	4, 22	5, 21	6, 20	7, 19	8, 18	9, 17	10, 16	11, 15	12, 14
2½	2.875	.3763	9.032	5.35	5.39	5.44	5.53	5.65	5.79	5.94	5.57	5.22	4.92	4.68	4.53
3	3.500	.4582	10.996	5.53	5.56	5.63	5.74	5.89	6.06	6.25	5.80	5.38	5.00	4.73	4.54
3½	4.000	.5236	12.566	5.67	5.70	5.78	5.92	6.09	6.29	6.50	5.98	5.52	5.13	4.79	4.57
4	4.500	.5889	14.137	5.78	5.83	5.91	6.05	6.25	6.48	6.73	6.17	5.63	5.15	4.81	4.56
4½	5.000	.6545	15.708	5.95	5.98	6.09	6.25	6.47	6.72	7.00	6.35	5.76	5.23	4.83	4.57
5	5.563	.7282	17.477	6.14	6.17	6.28	6.45	6.70	6.97	7.27	6.52	5.84	5.29	4.87	4.58
6	6.625	.8672	20.813	6.40	6.45	6.58	6.82	7.10	7.43	7.78	6.94	6.15	5.45	4.94	4.61
7	7.625	.9981	23.955	6.71	6.76	6.92	7.17	7.50	7.87	8.29	7.31	6.40	5.61	5.02	4.63
8	8.625	1.129	27.096	7.00	7.08	7.27	7.54	7.92	8.35	8.81	7.72	6.65	5.77	5.08	4.64
9	9.625	1.2599	30.238	7.34	7.42	7.61	7.92	8.34	8.81	9.33	8.06	6.90	5.88	5.14	4.66
10	10.750	1.4072	33.772	7.64	7.72	7.95	8.38	8.75	9.28	9.86	8.46	7.17	6.08	5.22	4.68
11	11.750	1.538	36.914	7.94	8.03	8.27	8.65	9.15	9.75	10.39	8.87	7.47	6.23	5.33	4.72
12	12.750	1.6689	40.055	8.21	8.30	8.57	9.00	9.55	10.17	10.89	9.22	7.69	6.38	5.37	4.73
14	14.000	1.8325	43.982	8.62	8.70	9.02	9.46	10.05	10.75	11.53	9.66	7.98	6.57	5.45	4.74
15	15.000	1.9635	47.124	8.88	8.96	9.28	9.78	10.42	11.17	11.95	9.96	8.15	6.65	5.49	4.74
16	16.000	2.0944	50.265	9.16	9.30	9.60	10.12	10.82	11.64	12.50	10.45	8.50	6.87	5.55	4.78
18	18.000	2.3562	56.548	9.72	9.86	10.22	10.81	11.60	12.52	13.48	11.15	9.00	7.16	5.70	4.82
20	20.000	2.618	62.832	10.37	10.48	10.90	11.56	12.40	13.41	14.48	11.88	9.50	7.48	5.90	4.85
24	24.000	3.1415	75.398	11.60	11.75	12.25	13.00	14.08	15.28	16.53	13.42	10.54	8.04	6.15	4.90
30	30.000	3.927	94.248	13.26	13.42	14.06	15.06	16.34	17.84	19.40	15.42	11.80	8.80	6.48	4.98
36	36.000	4.7125	113.100	14.94	15.22	15.94	17.12	18.70	20.54	22.46	17.80	13.50	9.82	6.90	5.14

NOTE—In all cases, the length of Ordinate No. 13 is 4.50

These Templets are Used on the Branch

Physical Characteristics of Metals

METAL	CHEMICAL SYMBOLS AND APPROXIMATE ANALYSES (PER CENT)	Melting Point Degr. Fahr.	Linear Expansion, per 10-Foot Length, per 100 Degrees Fahr. Rise in Temperature Inches	Heat Conductivity British Thermal Units per Hour per Sq. Ft. per Inch of Thickness per Degree Fahr.	Approximate Breaking Strength Pounds per Square Inch	Wght. P'ds per Cubic Inch	Shrinkage Allowance in Castings Inches per Foot	Patented, or Special Alloy, Manufactured by	Remarks
Allegheny Metal (page 250)		2640	0.115		90,000*-120,000	0.283		Allegheny Steel Company	*Annealed.
Aluminum—Cast—8% Copper	Al, 92; Cu, 8	1175			20,000		0.1875		
Aluminum—Pure	Al	1215	0.148	1393	12,000-28,000	0.096			
Aluminum—5% Silicon	Al, 95; Si, 5	1117	0.146		18,000	0.093		Aluminum Co. of America	
Ambrac A	Cu, 75, Ni, 20; Zn, 5	2100	0.109		50,000-130,000	0.310		American Brass Co.	
Antimony	Sb	1150	0.075		1000	0.245			
Boron	B	3992				0.094			
Brass—Common Yellow (rolled)	Cu, 65; Zn, 35	1652	0.115	756	46,000	0.303	0.1875		
Bronze—Manganese (page 164)		1598	0.119		60,000	0.302		American Brass Co	
Bronze—Phosphor (page 164)		1922	0.119		45,000	0.321		American Brass Co.	
Bronze—Roman	Cu, 60; Zn, 39; Sn, 1	1625	0.119		54,000	0.304		Revere Copper & Brass Inc.	
Bronze—Tobin (page 164)	Cu, 60; Zn, 39; Sn, 1	1625	0.119		54,000	0.304		American Brass Co.	
Carbon	C	†6332							†means greater than.
Chromium	Cr	2740				0.235			
Cobalt	Co	2700	0.082		34,400	0.312			
Copper—Deoxidized (page 249)	Cu, 99.9	1981	0.118		32,000-55,000	0.307	0.25		
Copper—Electrolytic (page 164)	Cu	1981	0.106	2640	20,000-70,000	0.322			
Duriron	Si, 14.5; C, 0.85; Mn, 0.35; Fe, base	2310	0.104			0.253	0.1875	Duriron Company	Acid-resisting iron. Wt. cast, 0.294 lbs. cu.in.
Everdur	Cu, 94.8-96; Si, 3-4; Mn, 1-1.2	1866	0.113	871	52,000-100,000	0.306	0.1875	American Brass Co.	
Gold	Au	1945	0.094	2046	14,000	0.697			
Iron—Cast		2300	0.067	338	15,000	0.260	0.125		
Iron—Malleable		2300			53,000	0.268	0.125		
Iron—Pure	Fe	2786	0.078	467		0.283			
Iron—Wrought		2900	0.078	419	48,000	0.278			
Lead	Pb	620	0.181	240	1780	0.411	0.312		
Lead—Chemical	Pb 99.92; Cu, 0.08	620	0.193		1780	0.410	0.312		
Manganese	Mn	2246				0.268			
Molybdenum	Mo	4532		100	42,500-154,000	0.309			
Monel Metal (page 243)	Ni, 67; Cu, 28; Fe, Mn, Si, C, 5	2400	0.093	174	79,000-109,000*	0.318			*Sheets from soft to full hard.
Nichrome	Ni, 60; Fe, 24; Cr, 16; C, 0.1	2460	0.091		100,000	0.295		Driver-Harris Co.	
Nickel	Ni	2640	0.083	413	61,000-109,000*	0.319	0.25		*Sheets from soft to full hard.
Nickel Silver (18%)	Cu, 65; Ni, 18; Zn, 17	1955	0.122		58,000-95,000	0.309			
Silicon	Si	2588							
Silver—Pure	Ag	1762	0.126	2919	36,000	0.380			
Steel—Hard (0.30-0.70% Carbon)		2500	0.076	312*	75,000	0.283			*1% Carbon.
Steel—Low Carbon (less than 0.15%)		2700	0.076		50,000	0.283			
Steel—Medium (0.15-0.40% Carbon)		2600	0.076		60,000	0.283			
Steel—Manganese	C, 1.0-1.45; Mn, 12.00-15.00; Si, 0.10-0.20	2400			70,000-100,000				
Steel—Nickel—3.5%	Ni, 3.25-3.75; C, 0.15-0.25; Mn, 0.50-0.80	2600			80,000	0.284			
Steel—Cast		2600			58,000	0.282	0.25		
Stainless Steel—Carpenter No. 4	Cr, 18; Ni, 9.5; C, 0.1; Fe, base	2550			89,000-100,000	0.279		Carpenter Steel Co.	
Stainless Steel	Cr, 8 and over; Mn, 0.4; C, ‡0.12; Fe, base	2640	0.073		80,000*	0.280		American Stainless Steel Co	*Annealed. ‡ means less than
Stainless Iron	Cr, 8 and over; Mn, 0.4; C, ‡0.12; Fe, base	2640	0.073		80,000*	0.280		American Stainless Steel Co.	*Annealed.
Stellite	Co, 43-55; W, 11-14; Cr, 25-34; C, 0.75-2.5	2305*	0.100		40,000-134,000	0.310		Haynes Stellite Co.	*Average
Tin	Sn	450	0.139	450	5,000	0.263	0.083		
Tungsten	W	6152		1381		0.678			
Vanadium	V	3182				0.199			
Zinc—Cast	Zn	786	0.169		9,000	0.248	0.312		
Zinc—Rolled	Zn	786	0.169	770	31,000*	0.258			*Average hard rolled.

References—Kent's Mechanical Engineer's Handbook; Sterling's Marine Engineers' Handbook; Machinery's Handbook; Chemical and Metallurgical Engineering and other sources.

Chapter No. 6

Arc Welding

Lesson No. 1

Electric Circuits and Arc Welding Equipment

Electricity

ELECTRICITY is a fact of nature. It is in existence everywhere like air, but why it exists or what it is is not known. How it acts and what it can do, however, is known, and certain rules have been established which definitely govern its actions. As electricity is already in existence, it cannot be created. It is possible, however, to create a flow of electricity as a flow of water is created in a pipe with a pump. Such a flow of electrical current may be created by mechanical or chemical means and by heat.

In electric welding a current is produced by a rotating electric generator driven either by a motor, or by a gasoline engine. Current is also taken from the cables from an electric generating plant and transformed by means of an electrical transformer so that it will have characteristics suitable for welding. As stated above certain rules or laws have been developed pertaining to electricity, and the following are the commonly known electrical units.

Volt

In order to cause current to flow through a wire there must be an electrical pressure. This pressure is measured in volts, and is usually called voltage. It is also referred to as electromotive force, the abbreviation of which is e.m.f. It may be likened to the pressure of water in a pipe.

Ampere

An ampere is a unit of current strength, and measures the quantity of electricity flowing through the wire. It may therefore be compared to the volume of water which will flow through a pipe.

Ohm

An ohm is a unit of resistance to the flow of electricity through a wire, or other conductor. It would be the equivalent of the frictional resistance to the flow of water through a pipe.

Relationship of Electrical Units

These units have a definite relationship to each other, which may be expressed in this way:

A volt is the unit of electrical pressure necessary to cause a current of one ampere to flow through a wire the resistance of which is one ohm.

The ampere is therefore the quantity of current which will flow through the resistance of one ohm under a pressure of one volt.

The ohm is the amount of resistance through which a current of one ampere under a pressure of one volt will flow.

These three units are dependent upon each other, and one unit must be independently stated. This unit is the ohm. It is usually defined as the resistance to the flow of electricity of a certain size and form of conducting material, as for instance a copper wire of a given diameter.

The relationship between volts, amperes, and ohms has been determined as follows:

The current in amperes is equal to the pressure in volts divided by the resistance in ohms, or

The pressure in volts is equal to the current in amperes multiplied by the resistance in ohms, or,

The resistance in ohms is equal to the pressure in volts divided by the current in amperes.

Current flows in a circuit from one pole or terminal of an electrical generator through a wire to another pole. The pole from which the current flows is called the positive pole, or terminal, and the pole to which it flows is called the negative pole, or terminal.

Units of Work and Power

Another unit which must be considered in dealing with electricity is the watt. This is the unit of electrical power. Power may be defined as the rate at which work is done. It is independent of the total amount of work done. Work is accomplished when a force overcomes a resistance and moves a body on which it acts. Work is usually expressed as a force multiplied by a distance. Mechanically the force is usually expressed in pounds, and the distance in feet, and the result is expressed in foot pounds. An engine does work when it moves a train along the track. A generator does work when it produces a current of electricity.

Electrical work, however, is not ordinarily expressed in foot pounds, although it can be. It should be noted in this connection that if a force is applied to an object, as, for instance, an attempt is made to lift a weight, if the force is not great enough to lift it, no work has been accomplished, but if this force does lift it, the result is measurable in foot pounds. Work of this kind does not take into account the element of time. If for instance, a 50 pound weight is lifted four feet, it does not make any difference whether the weight is lifted this distance in a minute or an hour, the work done is 200 foot pounds.

Power Is Rate of Doing Work

Power has already been defined as the rate of doing work, and it must not be confused with the total work done. In electricity, the unit of electrical power is the watt. Electrical work consists in overcoming the resistance of a circuit, as in an electric lamp. The work in this case is developed as heat and light. When an electric motor is connected to a circuit, the work which is accomplished by the motor consists in turning a shaft to move a belt or to turn a gear driven mechanism to operate machinery. Electrical work is defined as the amount of work performed by a current of one ampere flowing for one second under a pressure of one volt. This is called a joule. By experiment a joule has been found to be equivalent to 0.7375 foot pounds of mechanical work.

A watt is equivalent to the electrical power of one joule per second. Watts are expressed in an electrical circuit as volts times amperes. One watt equals one volt multiplied by one ampere. In order to find the rate in watts at which electrical energy is expended in a circuit, multiply the current in amperes by the pressure in volts, causing it to flow. It must be remembered that electrical machines are not fully efficient, and the percentage of efficiency must be taken into account.

Kilowatt

A kilowatt is a larger unit of power consisting of 1000 watts. As previously indicated, one watt equals 0.7375 foot pounds per second. Five hundred and fifty foot pounds per second are equivalent to one mechanical horse power. An electrical horse power would therefore be equivalent to 746 watts. The electrical horse power is a convenient unit because the watt is a very small one. One thousand watts or one kilowatt is equal on the same basis to 1.34 electrical horse power or one electrical horse power equals 0.746 kilowatts. A kilowatt-hour is the ordinary unit of electrical work, and is equal to 1,000 watts, or one kilowatt, maintained for one hour. An electrical horse power-hour is one electrical horse power maintained for one hour, or 746 watts per hour.

Direction of Flow of Current

Direct current, to which the previously stated relationship of volts, amperes, and ohms refers, is a current moving in the same direction around a circuit. Alternating current is a current which changes its direction of flow at regular intervals of time, much shorter than one second. For transmission and distribution in electrical systems alternating current has several advantages over direct current, and for this reason most of the current generated today for power and other purposes is alternating. With alternating current it is possible to use much higher voltage. The voltage of direct current is not as readily changed as with alternating current. With direct current a motor generator set is ordinarily used, while with alternating current the change may be easily made with a transformer.

Cycle and Frequency

In alternating current circuits the current is forced from zero to its maximum value in one direction and back to zero; and then to its maximum value in the other direction and back to zero. This complete set of values passing through a circuit in a certain period of time is called a cycle. This cycle of changes takes place in a length of time called a period, and the number of complete periods in one second is called the frequency of the pressure or current. This change of direction in the current is produced by a machine called an alternator, and if the change takes place sixty times per second, the current is said to have a frequency of 60 cycles.

What Is k.v.a.?

There are certain other terms which are used in connection with welding machines with which the welder should be familiar. One of these is signified by the abbreviation k.v.a.

This expression is defined as follows:

K.v.a. means volts times amperes divided by 1000. The term is used only in alternating current practice, and is used to represent the apparent load on a generator.

When an alternating current flows through a wire, it sets up a magnetic field about this wire. If the current is broken, the magnetic field is changed which induces a current in an adjacent wire. This characteristic is called inductance. This principle is mentioned later under transformers.

When alternating current passes through a wire the current is broken many times a second by the alternator. This not only induces a current in nearby wires, but also a current in the current-carrying wire itself, which unfortunately is in the opposite direction to the flow in the original wire. This opposition to the flow of current is an additional resistance besides the resistance of the conductor itself, and is called inductive reactance.

To find	Direct Current	Alternating Current Single Phase
Amperes when horsepower is known	$\frac{\text{Horsepower} \times 746}{\text{Volts} \times \% \text{ efficiency}}$	$\frac{\text{Horsepower} \times 746}{\text{Volts} \times \% \text{ efficiency} \times \text{power factor}}$
Amperes when kilowatts are known	$\frac{\text{Kilowatts} \times 1000}{\text{Volts}}$	$\frac{\text{Kilowatts} \times 1000}{\text{Volts} \times \text{power factor}}$
Amperes when kilovolt-amperes are known	....	$\frac{\text{Kilovolt-amperes} \times 1000}{\text{Volts}}$
Kilowatts	$\frac{\text{Volts} \times \text{Amperes}}{1000}$	$\frac{\text{Amperes} \times \text{Volts} \times \text{power factor}}{1000}$
Kilovolt-amperes	....	$\frac{\text{Amperes} \times \text{Volts}}{1000}$
Horsepower (output)	$\frac{\text{Amperes} \times \text{Volts} \times \% \text{ efficiency}}{746}$	$\frac{\text{Amperes} \times \text{Volts} \times \% \text{ efficiency} \times \text{power factor}}{746}$

It is therefore necessary in a generator or a welding machine to increase the electrical input of the machine sufficiently to overcome this additional resistance as well as the normal resistance of the machine. The input of alternating current machines is measured in kilovolt amperes, and is commonly called k.v.a. Therefore the kilowatt demand of a welding machine represents the actual useful power consumed in welding, while the k.v.a. demand is the power consumed in welding plus that required to overcome inductance. The k.v.a. demand governs the size of the wire which is used in connecting the welder to the power lines. The kilowatt demand divided by the k.v.a. demand of any machine represents the power factor or the percentage of efficiency of the machine.

Open Circuit Voltage

Another expression which is often used which may be puzzling is open circuit voltage. This is the potential voltage or pressure in the circuit when no arc has been made between the electrode and the work; in other words, when no welding is being done.

When the circuit is open no current flows, but the pressure or voltage exists nevertheless. In order to appreciate what voltages are required for welding, the following general figures may be of interest.

With direct current the open circuit in metallic arc welding usually is from 50 to 80 volts, and with alternating current from 70 to 135 volts, depending of course upon the equipment in use. Ordinarily the voltage across the arc in metallic arc welding is from 15 to 26 volts with ordinary bare electrodes, and up to 45 volts with heavily coated electrodes.

The Metallic Arc Circuit

Figure 1 illustrates one of the simplest types of electric welding equipment wherein a transformer reduces the current from an ordinary power line to a suitable voltage and amperage, that is, to a suitable pressure and volume of current, for welding purposes. A copper insulated cable from the transformer is attached to an insulated handle with a projecting device for gripping the electrode. The electrode is a short piece of metal wire either bare or coated. Another copper insulated cable is attached to the other pole of the transformer, and with a weight or clamp, to the piece of metal which is to be welded. As long as the electrode is kept away from the metal to be welded no current flows, and there is no circuit. The moment, however, that the electrode is brought in close proximity to the metal the electric current overcomes the resistance of the very small air gap between the electrode and the metal to be welded, and causes an arc or flame having a temperature in the neighborhood of 6000 degrees F. This melts the electrode, and the metal to be welded, and by proper movement of the electrode enables the welder to produce a fusion weld.

Arc Flame Extensively Studied

The characteristics of the arc flame have been studied by scientists extensively and the manner in which the metal of the electrode is transferred through the arc to the parts being welded has been the subject of extensive research. It is a very complicated subject about which several chapters might be written, and is one which we cannot consider here because of the general treatment of the subject and the fact that such knowledge is not essential to actual welding procedure.

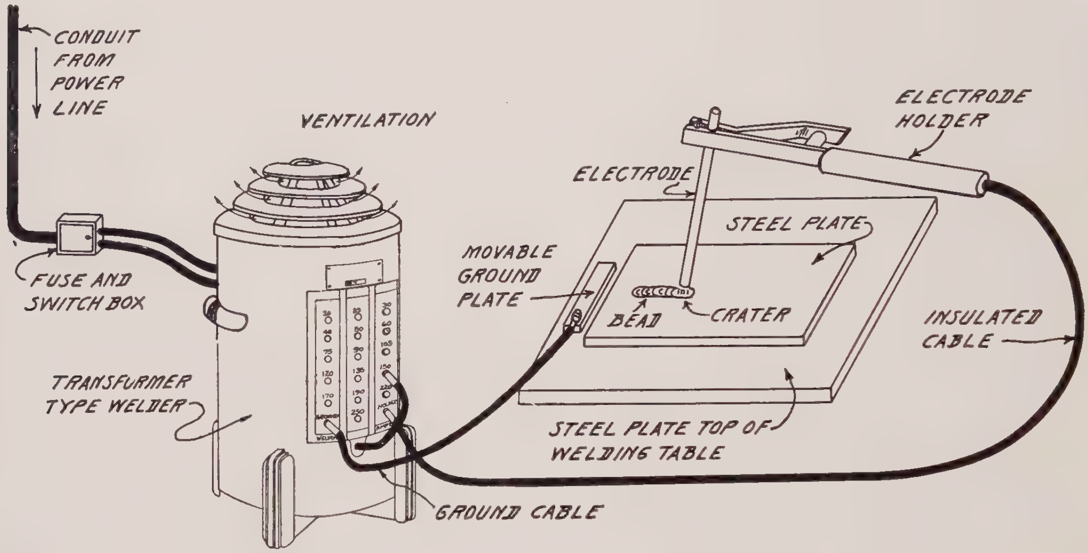


Figure 1—Sketch Showing a Simple Arc Welding Circuit Using a Transformer from an Alternating Current Power Line. Various Parts of this Circuit are ClearlyIndicated by Name.

Protection for the Eyes and Body

Before going further with this discussion, it is desirable that the student know how to protect himself from the brilliant rays of the electric arc. Such protection for both eyes and skin is even more necessary than with the oxy-acetylene flame. For this reason arc welders wear either a helmet, or use a hand shield to protect the eyes and face.

In the front portion of both the helmet and the shield will be noticed a rectangular window of special glass which will filter out injurious rays. This glass is properly tinted to give the greatest protection possible for the eyes. In holding a hand shield a glove should always be worn on the hand holding the shield as well as on the hand holding the electrode holder.

For most purposes the welding helmet is generally worn, because it affords full protection and allows free use of both hands. Some of these helmets are arranged so that they tip back over a man's head, to give him vision without looking through the dark glass for preparation of the weld before striking the arc, and for treatment of the finished weld after the arc is extinguished before proceeding with another weld.

Protective Clothing Necessary

In arc welding there is often considerable spatter of hot particles of metal which, if they light upon the clothing, are likely to burn through. Such burns are not always easy to heal, and the welder should therefore take care to prevent them. One of the principal causes of trouble is the wearing of low shoes. A welder should wear high shoes and should not have cuffs on his trousers, because they are likely to catch particles of metal and burn.

There is a great deal of special clothing made for welders including fire-proofed cloth spats, to protect the feet, leather aprons, fire-proofed cloth trousers, jackets, etc., which may or may not be necessary, depending upon the kind of a job to be done. If it is a very hot job, or if a good deal of overhead work is necessary, the welder should protect himself thoroughly to avoid burns.

Other Workmen Must Be Protected

When an electric welder is set up in a shop where other workmen are employed, it is necessary to surround the operator and the machine with asbestos or fire-proofed cloth curtains, hung from rails made of pipe, so that intermittent flashing of the arc will not interfere with other work. This is usually accomplished by making a welded pipe frame and curtaining off each electric welding machine and operator with such curtains.

Welding Table

An excellent form of welding table is one which can be quickly made with a piece of steel plate of any available size and from ⅜ to ½ in. thick. This may be welded to four pieces of pipe constituting legs with suitable stretchers, angular brackets, etc. In Fig. 6 such a table is shown together with several forms of ground clamps.

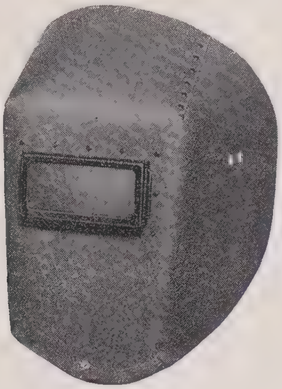


Figure 2—Photograph of a Welding Helmet. Some of These Helmets Tip Back When the Operator is Not Welding, and Others Are Arranged so That the Frame Holding the Window in the Front of the Helmet May be Tipped up to Permit Vision.

Ground Clamps

It is often desirable to be able to move the clamp to different positions on the table in order to lessen arc blow, which is a magnetic disturbance of the arc. The ground clamp therefore is sometimes merely a heavy piece of steel to which the cable is attached or it may be a C clamp or a spring clamp which grips the table and may be moved from point to point as desired. In such cases the work is merely laid on the table. Sometimes it is desirable to attach the ground clamp to the work itself. It is therefore essential that this cable connection be as flexible as possible to enable its quick movement if required.

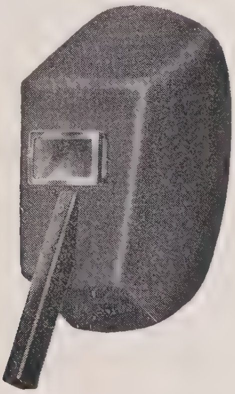


Figure 3—Photograph Showing a Hand Shield.

Electric Welding Machines

There are a number of different types of electric welding machines which will be described generally as follows:

Fig. 8 illustrates a machine of the transformer type. Transformers are made to reduce the voltage of the current from a power line to a suitable voltage for welding. This is accomplished by winding a primary coil of insulated wire around a soft iron core, and winding a secondary coil of insulated wire around this primary coil. When an alternating current is run through the primary winding there is a constant change in magnetic forces which produces a current in the secondary winding. The reduction in voltage of the current is accomplished because of the difference in the number of turns of the wire in the coils.

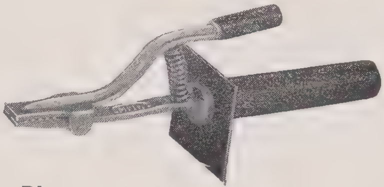


Figure 4—Photograph Showing an Electrode Holder. This Holder is Attached to One of the Cables Leading to the Welding Machine.

In Fig. 1 the power lines carrying a current of 220 volts, alternating current, at 60 cycles and variable amperage are connected to the terminals at the back of the transformer. In the front of the machine will be noted a panel having a socket for the ground cable to the ground clamp attached to the work, and another socket to the right of the panel for the cable which extends to the electrode holder. These are marked respectively ground and holder. It will be noted that there is a cable leading from the machine to which a plug is attached. In the illustration this cable is plugged into the 250 amperes socket. This plug can be moved to any socket which will then produce a current in the welding circuit equivalent to the number of amperes indicated.

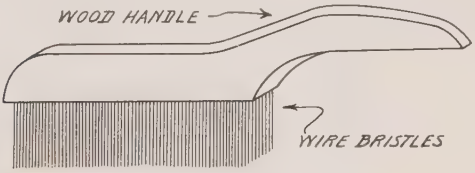


Figure 5—Wire Brushes Are Very Useful to Clean the Metal Before Beginning to Weld, and to Brush Away Any Oxide or Slag Which May Accumulate During Welding.

Rotary Type Machines

In Fig. 9 a rotary type machine is illustrated. This is a motor, usually driven by 220 volts alternating current. In districts where only direct current is available, such motors may be driven by 220 volts direct current. The motor is connected to a single shaft upon the other end of which is an electric generator. This electric generator, driven by the motor at the same speed produces a current having proper characteristics for welding. These machines are mounted in a suitable frame and are ordinarily called motor generator sets. The current is adjustable as to voltage and amperage, or both.

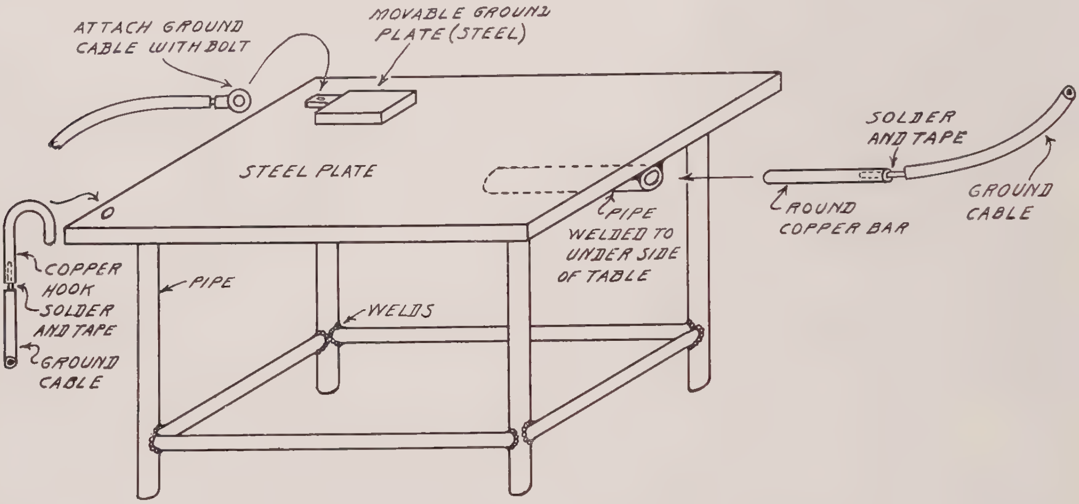


Figure 6—Sketch Showing a Typical Welding Table.This Table is Made With a Steel Top, and Welded Pipe Legs. Typical Ground Connections Are Also Shown.

Another type of rotary machine is a generator driven directly by a gasoline engine. This type of machine is mounted upon a suitable chassis, and in many cases is built as a trailer unit which can be hauled by an automobile as a portable machine for outside work.

Alternating and Direct Current

In a welding circuit when direct current is used greater heat is developed at the positive pole than at the negative pole. It is frequently said that two-thirds of the heat produced by the arc is at the positive pole, while the other third is at the negative pole. For this reason, in direct current welding with bare electrodes, the positive cable is ordinarily connected to the work, and the negative cable to the electrode. This is done because, as a rule, the work or the piece being welded, is of larger volume and there is greater conductivity of heat. Better distribution of heat is thus obtained than if the current were reversed. This manner of connecting the leads of a direct current circuit is called straight polarity. When covered electrodes are used, or non-ferrous electrodes, like bronze or other metals lacking iron, it has been found that more heat is required at the electrode, in order to melt both the electrode and the coating, and that the circuit works better when the electrode is made positive and the work negative. This is called reversed polarity. Usually on the newer direct current machines a switch is provided to quickly change the polarity.

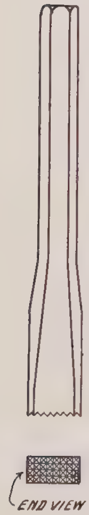


Figure 7—Type of Tool Which is Used for Removing Slag. It is Especially Important That Slag be Removed From Welds Already Made Before Making New Beads. Good Tools Will Accomplish This Purpose.

Alternating Current

With alternating current the polarity automatically changes itself many times a second, and thus polarity is not a factor, and the heat at either pole of the circuit is the same.

Electrodes

Electrodes are made in many types. The first to be considered are those normally called bare electrodes.

These are pieces of mild steel wire 14 inches long, of varying diameters, usually from $\frac{3}{32}$ to ¼ inches. Such electrodes are not coated in any sense except that they may contain lime impregnated in their surfaces caused by the wire drawing process. They may also be sul-coated, which coating is produced by slightly rusting the wire during the process of drawing. Either the lime or the sul-coated finish tends to stabilize the arc by producing a better current-carrying atmosphere in the vicinity of the arc.

Another type of electrode is the thinly coated electrode. These are mild steel electrodes with a very thin dusted, or washed, coating applied to them to improve the stability and performance of the arc stream.

Shielding the Arc

Heavily coated electrodes are mild steel electrodes the coating of which is designed to materially improve the strength and ductility of the deposited weld metal. This is accomplished by shielding the arc from the action of the oxygen and nitrogen in the air by gases developed from the coating material as it burns. Another type gives this same protection by means of gases and slag both developed from the coating material. The slag covers the weld, and slows down the rate of cooling at the same time protecting the molten metal from the atmosphere after the weld has proceeded beyond the zone protected by the gases.

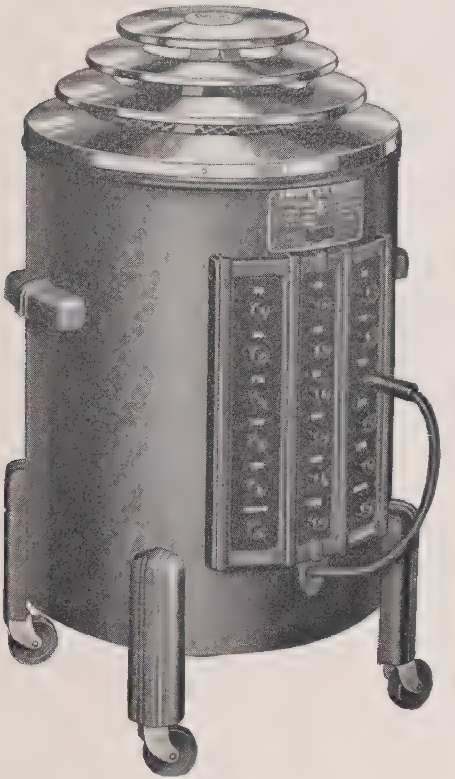


Figure 8—Photograph Showing a Typical Transformer Type Welding Machine.

Try These Tests

When using bare electrodes considerable amounts of oxygen and nitrogen from the air are absorbed by the molten metal, resulting in the inclusion of oxides and nitrides in the weld metal. For this reason a weld made with bare electrodes does not possess the strength or ductility of a weld made with heavily coated electrodes. This can be quickly determined by the welder if he will make a weld between two pieces of bar steel, and place these welded pieces in a vise so that a bend may be made in the weld itself. Usually a weld of this type will bend perhaps 45 or 50 degrees from its former straight position when the weld metal will begin to crack, indicating considerable brittleness.

If similar pieces of steel are welded with a coated electrode in exactly the same manner and the pieces placed in a vise, and bent in the same manner through the weld, it will be found that the weld metal will usually permit a bend of 180 degrees without breaking. In other words, the weld metal produced by a covered electrode, having been protected from the action of the oxygen and nitrogen in the air, is much more ductile and has greater strength than the deposited metal from a bare electrode.

Coated Electrodes

There are two general types of coated electrodes, one called gas-shielded electrodes, and the other called gas and slag-shielded electrodes.

The gas-shielded electrode is usually coated with materials producing only gases, while the gas and slag-shielded electrode is coated with materials producing gases and a slag coating which may be readily chipped away after the weld is completed. Coated electrodes require a greater amount of heat in the arc than bare electrodes, and usually the speed of welding is considerably increased.

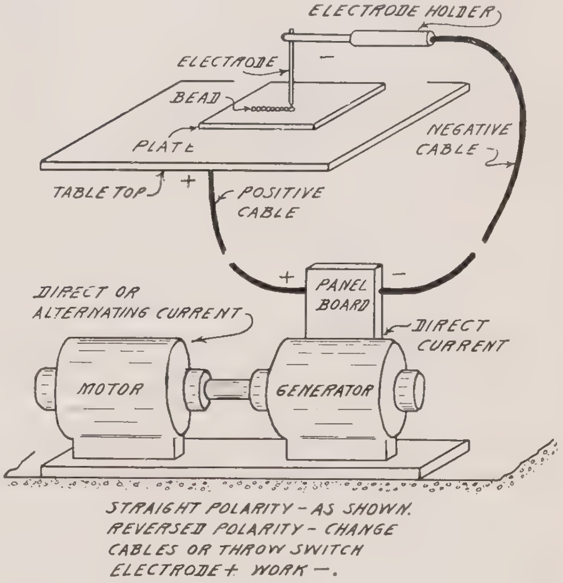

ELECTRODE HOLDER
ELECTRODE
−
BEAD
PLATE
NEGATIVE CABLE
TABLE TOP
+
POSITIVE CABLE
+
−
PANEL BOARD
DIRECT OR ALTERNATING CURRENT
DIRECT CURRENT
MOTOR
GENERATOR
STRAIGHT POLARITY - AS SHOWN.
REVERSED POLARITY - CHANGE CABLES OR THROW SWITCH ELECTRODE + WORK −.

Figure 9—Sketch Showing a Rotary Type Motor Generator Set.

The lightly fluxed or dust coated electrodes do not completely shield the arc, but they do produce a more stable arc because through their action, better conductivity of the air surrounding the arc is produced than if a bare electrode were used.

Electrodes Should Be Carefully Studied

The kind of electrode which should be used with direct or alternating current is a matter which should be given careful consideration by the welder. Bare electrodes can be used with either current, but the tendency in modern welding is to use the stronger faster electrodes, which are the coated type. Electrodes are supplied by most manufacturers with specific directions printed on the package or in their catalog. These indicate whether they should be used on the positive or the negative side of a direct current circuit, and whether or not they are suitable with an alternating circuit. Some electrodes are not suitable at all for alternating current, while others may be used with either.

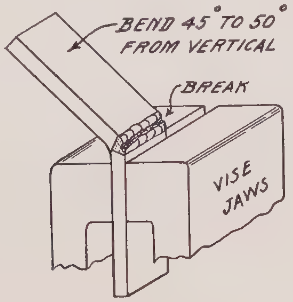


Figure 10—Sketch Showing a Bend Test of Two Steel Bars With the Weld Broken as Described.

Some electrodes, because of the coating, produce better results in a horizontal position. Others may be used in all positions, that is, horizontal, vertical, or overhead. The positions for which electrodes are best adapted are also stated by the manufacturer in his catalog.

Questions

1. What is meant by the term voltage?
2. When flowing through a pipe, what characteristic of water might be likened to the amperage of an electric current?
3. What characteristic of an electric circuit does the ohm represent?
4. State generally the relationship of these units.
5. What is a watt?
6. How many watts are there in an electrical horsepower?
7. What is meant by open circuit voltage?
8. What is meant by the term k.v.a.?
9. What is meant by e.m.f.?
10. How should the eyes and the body be protected from the arc?

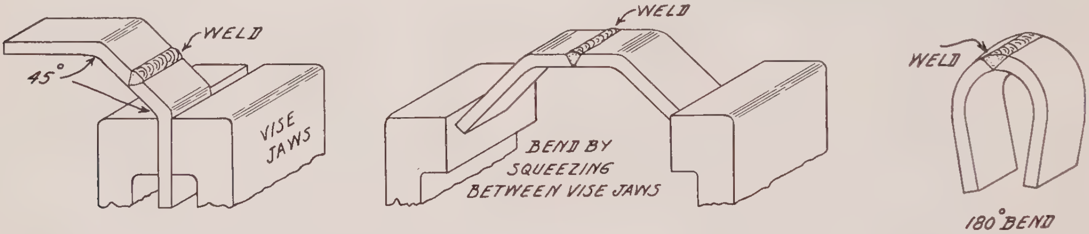


Figure 11—Sketch Showing a Bend Test of Two SteelBars Bent to 180 Degrees.

When using direct current, a coated electrode is ordinarily connected to the positive pole of the circuit. Whether or not it may be used satisfactorily with alternating current, or if direct current is used, whether the electrode should be positive or negative is dependent upon the ingredients used in the coating. It is therefore necessary for the welder to become familiar through the manufacturer with the correct use of such electrodes, and follow directions so that he may produce satisfactory welds.

11. Describe a good form of welding table with a ground clamp.
12. Describe generally three types of electric machines which are used to produce welding current.
13. What is alternating current?
14. What is the difference between a bare electrode and a shielded arc electrode?
15. What is the difference in the weld metal deposited by a bare and a coated electrode?

Lesson No. 2

Preliminary Steps In Welding

Connecting Equipment

IN connecting any welding equipment the manufacturer's directions should be very carefully studied to determine just how this equipment should be connected to the power supply. If it is a transformer type of equipment which is in use, the connections for leads to the power line will be indicated, but only a skilled electrician should make such a connection. Interference with a power line is serious, and should not be attempted by anyone except a man thoroughly familiar with such work. When a machine is set up and connected, the two leads to the welding electrode and work can be very simply plugged into the machine, and this can be taken care of by the welder. There is no likelihood of any serious trouble in so far as current is concerned, and he need not fear that he will get a shock which will do any damage.

As stated before, the principal thing he must look out for is to protect himself from the rays of the arc with proper clothing and gloves, and to protect his eyes with a helmet or shield, and the eyes of others by proper screening off of the job he is doing. With an alternating current transformer type machine the leads from the transformer to the work and electrode holder are normally interchangeable because of the constant change in polarity of alternating current.

In the machine illustrated in Figure 8 the ground socket is plainly marked "ground," and it is merely necessary to plug in the plug attached to the cable provided with the machine and connect it to the ground clamp attached to the table or to the work. The other lead is connected to the electrode holder, and is plugged into the socket marked electrode.

When the cables to the ground clamp and the electrode holder are plugged into sockets of the machine, the amperage control cable should be plugged into the correct socket for the amperage required. Welders often refer to amperage as "heat," and in this respect it is somewhat like picking the proper size tip for the oxy-acetylene torch.

For the striking of the arc and the first bead to be welded a ¼ in. steel plate and a ⅛ in. steel electrode have been selected. The usual amperage for this thickness of metal and electrode would be 125 amperes. Therefore the amperage plug should be placed in the socket marked 125 amperes. The machine is now ready to start, and care should be taken that the electrode holder is not lying on the table, otherwise a circuit will be formed the moment the switch is turned on, unless an insulated holder is in use. It should be hung by the cable over a hook on the wall, or otherwise placed so that it will not contact the table. The switch above the welding amperage socket board on the machine may now be turned on to its proper position, and the machine is ready for operation.

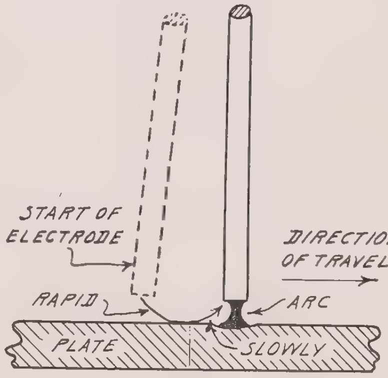


Figure 12—This Sketch Shows the Method of Striking the Arc Upon the Plate. It is Much Like Striking a Match, But Care Must be Taken That at the End of the Stroke the Electrode is Held at the Correct Distance From the Plate, and Moved as Soon as the Arc Forms, Continuing the Movement as the Weld Progresses.

Striking the Arc

The student should lay a steel plate ¼ in. in thickness and of any convenient size on the steel table to which the ground cable is connected. A ⅛ in. bare or lightly coated steel electrode should be placed in the electrode holder and the arc should be struck with a movement similar to the striking of a match, and then drawn away, as the arc forms, approximately $\frac{1}{8}$ in., which would be the proper length of arc for an electrode of this diameter (Figure 12). It is absolutely essential that the beginner practice striking the arc and maintaining it again and again until he is proficient, and can do so without permitting the electrode to stick to the plate.

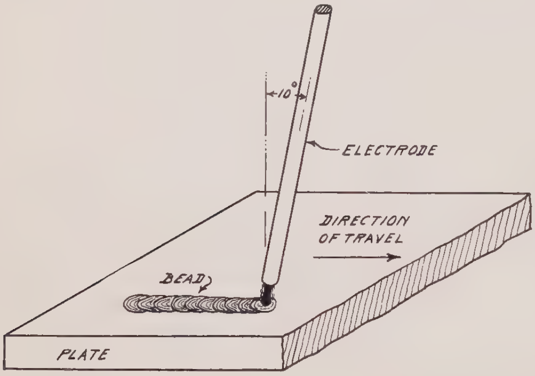


Figure 13—The Position of a Steel Electrode With Reference to a Steel Plate is Shown in This Sketch of a Straight Bead Made Without Lateral Motion of the Electrode.

Diameter of Electrode in Inches	Plate Thickness in Inches	Approximate Number of Amperes Required
$\frac{1}{16}$	Plates up to $\frac{3}{16}$	50-100
$\frac{3}{32}$	Plates up to $\frac{1}{4}$	100-150
$\frac{1}{8}$	Minimum Thickness $\frac{1}{8}$	125-175
$\frac{5}{32}$	Minimum Thickness $\frac{1}{4}$	150-200
$\frac{3}{16}$	Minimum Thickness $\frac{3}{8}$	175-350

It is difficult to set forth definite figures with reference to the settings of the machine for amperage in relation to the diameter of the electrode, and thickness of the plate being welded. An approximation only can be given, and the amperage cable plugged into the nearest socket available. The exact amperage required will depend upon many factors. The accompanying table is an approximation for bare and lightly coated electrodes. Heavily coated electrodes require greater values, and the weld metal is deposited with correspondingly greater speed.

In making a continuous deposit on the plate, usually called a bead, the electrode is held either vertical or at approximately 10 degrees from the vertical and moved in a straight line along the plate, at the same time moving the electrode downward toward the plate as the end of the electrode melts. This position is indicated in Figure 13. If the electrode is held too close to the plate a continuous flow of molten metal will weld the molten end of the electrode to the plate, and make it stick, that is, the arc will go out. In case this happens, it is necessary to slowly rock the electrode back and forth at the same time pulling upon it to break it loose from the plate. If this is done promptly the moment the electrode is felt to stick, it can be broken away without difficulty, and the current will again form an arc. If the electrode sticks fast, and becomes red hot, it will then be necessary to shut off the current, or loosen the grip on the electrode, and allow it to cool. When cold, it may be broken away readily with a pair of plyers. If the electrode is held too far away from the plate forming a long arc, the plate will not be melted and spatters or drops of metal will flow toward it, but a weld will not be made.

At this point in the discussion the student should understand just what is meant by the word "crater." When the arc is struck on the plate the heat melts a pool of liquid metal in the surface of the plate, and the force of the arc depresses this pool somewhat producing what is known as a crater, or a depressed pool of molten metal. The depth of this crater is called the penetration of the arc. Perhaps the best way to clearly understand these terms is to refer to sketches Figures 14 and 15 which show diagrammatically the plate, electrode, crater, and other features of a bead of deposited metal similar to that described.

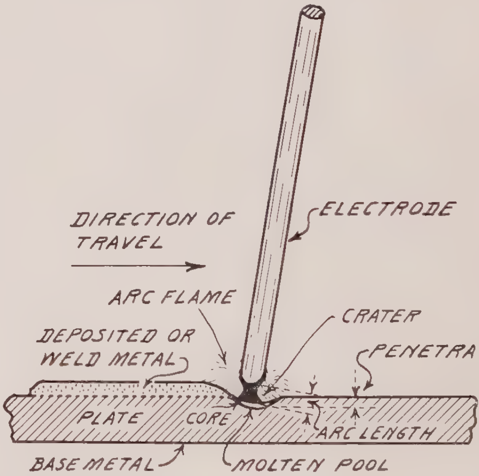


Figure 14—The Principal Characteristics of the Arc Are Shown in This Sketch, When a Bare or Lightly Coated Steel Electrode is Used to Weld a Bead on a Steel Plate.

Figure 14 is a sketch showing these features with reference to bare or lightly coated electrodes, whereas Figure 15 shows the same features in connection with heavily coated electrodes. The distinction between these two electrodes should be carefully noted. The latter type is called shielded arc electrodes.

Perhaps the best way in which the student can gain the experience necessary to hold the electrode at the proper angle, and move it in a straight line in the direction of the weld, at the same time moving it downward towards the plate, is to practice these movements without the current turned on. This will give him steadiness of hand and enable him to keep the electrode hovering over a point close to the plate, but not touching it. The difficulty which every student has in the beginning is to strike the arc without having the flash blind him because he has not put his helmet down quickly enough. He must learn to hold the electrode close to the plate at the point where he wishes to start, flip down his helmet, and strike the arc almost without seeing. If he strikes the arc first, and then puts the helmet down, the brilliance of the arc will blind him momentarily, preventing his seeing properly through the dark glass window of the helmet.

Practice will cure this difficulty, and the student should continue striking the arc and making a short bead on the plate until he becomes proficient. He should also practice continuing the bead previously made along the plate in the proper manner. When the arc is struck again after discontinuing the bead, it should not be started from the weld metal, but from the plate itself, and carried quickly upward to the weld metal already deposited, and continued at the advancing edge of the crater in the direction of welding. This is clearly indicated in Figure 16.

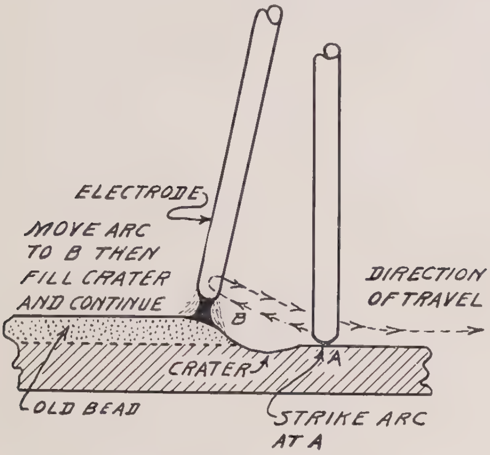


Figure 15—The Characteristics of Shielded Arc Welding Are Given in This Sketch. In Shielded Arc Welding a Heavily Coated Steel Electrode is Used Which Produces in Some Instances Gas, and in Others, Gas and Slag, to Shield and Protect the Molten Metal From the Oxygen and Nitrogen in the Air.

Proper Length of Arc

At this point a few words may be of value pertaining to the correct length of arc, and the manner in which the arc sounds when properly operated. It should be clearly understood that there is a distinct difference between the arc length of heavily coated, and bare or lightly coated electrodes. The heavily coated, or shielded arc electrodes, require a longer arc, much greater voltage, and more amperes or "heat." This discussion at present will refer to the bare and lightly coated steel electrodes. The length of arc used with such electrodes is ordinarily the diameter of the electrode. In other words, with a 1/8 in. electrode the arc length would be 1/8 in., with a 1/4 in. the arc length would be 1/4 in., etc. This is not absolutely true, but it is an approximation which the student should attempt to follow. Another good rule, which is easy to remember in connection with these electrodes, is that the amperage is approximately equal to the diameter of the electrode reduced to decimals. 1/8 in. is equal to .125 in., and with this diameter 125 amperes may be used. 1/4 in. is equal to .250 in., and a 1/4 in. electrode may be used with 250 amperes. This again is an approximation, and the number of amperes or the amount of "heat" used depends upon the exact conditions of welding, that is, the thickness of the plate being welded, the type of joint, and the diameter of the electrode.

If it is found after striking the arc that there is not sufficient penetration or depth of crater, the amperage should be increased until sufficient "heat" is available. Likewise if there is too much "heat" so that the arc is not controllable, and the metal is melting and being burned, the amperage should be reduced to a point where the arc can be controlled, and at proper length will give off a continuous snapping sound which will become very familiar to the ears of the student if he listens to a skilled welder accomplishing such work. If the arc is too long it will give off a hissing sputtering sound, and the metal as it passes from the electrode to the plate will be visible in drops, and there will be considerable spatter or particles of metal which strike the cold plate, and do not properly adhere to it.

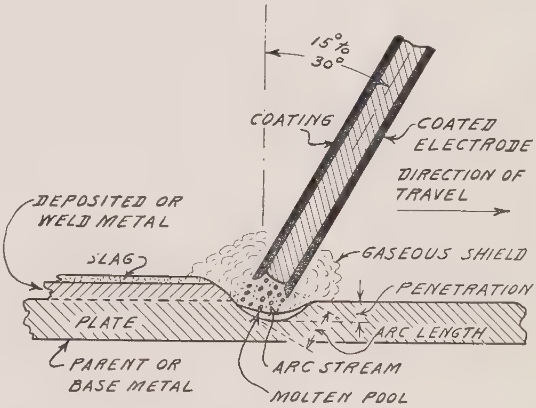


Figure 16—In Restarting a Weld, the Arc Should Never be Struck on the Old Weld Metal. It Should be Struck First on the Plate, and Then Quickly Moved up to the Old Deposit, and the Bead Continued as Usual, Filling the Old Crater and Continuing the Weld.

Direct Current Equipment

While this discussion so far deals especially with alternating current equipment practice, procedure with direct current apparatus would not differ materially except that the polarity or direction of flow of the current of the machine must be taken into consideration. As previously stated, the positive pole of a direct current machine gives off greater heat, some authorities giving the amount as two-thirds of the total heat developed by the arc, at the positive pole, and one-third at the negative pole. This condition prevails principally with bare and lightly coated electrodes, but with heavily coated electrodes it may be changed by the coating. It is stated that with some electrodes even more heat is produced at the negative than at the positive pole.

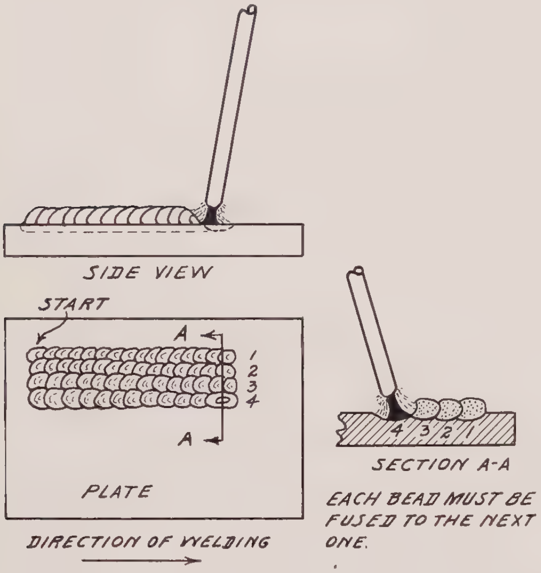


Figure 17—Parallel Beads Should be Made as Indicated, Being Sure That Each Bead is Fused into the Plate and into the Deposited Metal Forming the Bead Next to it. The Electrode is Tilted Slightly the End Pointing Toward the Bead Already Made, Which Assists in Fusion of This Bead. This Exercise Should be Practiced Again and Again Until the Student is Able to Accomplish a Uniform Cross Section When the Plate is Cut With a Hack Saw and the Section of the Weld Filed.

With bare and lightly coated steel electrodes when welding steel, the positive cable of the circuit is connected to the work, and the negative cable to the electrode (Figure 9). This is termed straight polarity. If, on the other hand, bronze or other copper alloy electrodes, or some types of heavily coated electrodes are in use, it is general practice to connect the positive cable of the circuit to the electrode holder, and the negative cable to the work. This is called reversed polarity.

In many of the direct current machines a switch is supplied on the panel board which will enable the welder to make this change of polarity quickly and conveniently. It has thus become common practice in direct current welding to call the electrodes positive or negative electrodes depending upon which cable of the circuit is to be connected to the electrode holder. Some coated electrodes operate equally well with either polarity, while others may be either negative or positive electrodes depending upon the coating. The welder must become familiar with the detailed directions of the manufacturer in connection with each electrode which he uses so that he will know without expensive experimental work whether the electrode can best be used on the positive or the negative side of the circuit. As stated before, polarity is not a factor when welding with alternating current, because the direction of current is rapidly changing many times per second.

Parallel Beads

Before proceeding with any of the other movements of welding the student should continue practicing on the plate by running parallel beads, one merging or melting into the other, as indicated in Figure 17. In some instances where such procedure covers a considerable area this is called padding, but it is good practice, and great care should be taken to be sure that each parallel row of deposited metal has been fused with the plate and also with the adjacent bead.

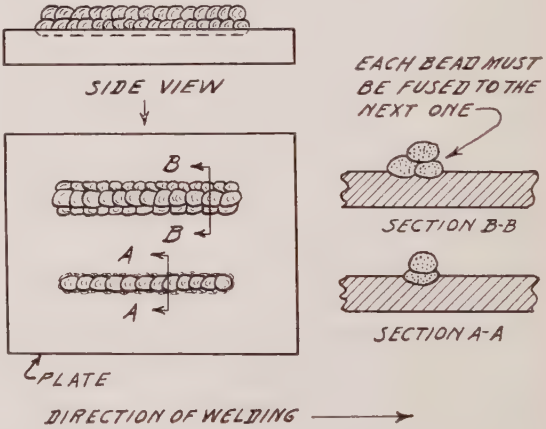


Figure 18—In Section A-A Two Beads Are Shown, One on Top of the Other. Care Must be Taken That the Upper Bead is Made the Same Width as the Lower Bead. Considerable Skill is Required to Produce This Result. Section B-B Shows Three Beads Fused Both to the Plate and to Each Other, to Make a Solid Weld. Great Care Must be Taken to Thoroughly Clean Each Bead Before the Next One is Made.

The next step is to build one bead over the top of one already made. It is absolutely essential that the first bead be thoroughly cleaned before the second bead is applied. Slag must be removed when cold with a proper tool, and the bead must be thoroughly wire-brushed to be sure that all oxide and scale has been cleaned away. This should leave the metal with a bright surface. When two parallel beads have been deposited upon the plate, a third bead should be run on top of the line of junction of these two beads as indicated in Figure 18. Again caution must be used to be sure that the new bead penetrates the beads already made on the plate, in other words that thorough fusion is gained, and not merely adhesion to the metal already deposited.

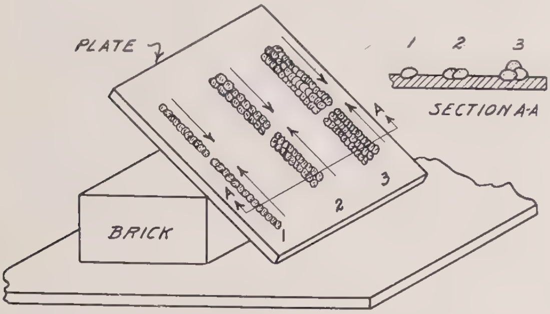


Figure 19—This Sketch Shows a Plate With One, Two, and Three Beads Welded at an Angle of 45 Degrees. The Plate Should be Tipped up More and More as Similar Beads Are Made, Until the Welder is Welding the Beads Vertically. He Should Weld the Beads Beginning at the Bottom and Welding Up, and Also Beginning at the Top and Welding Down.

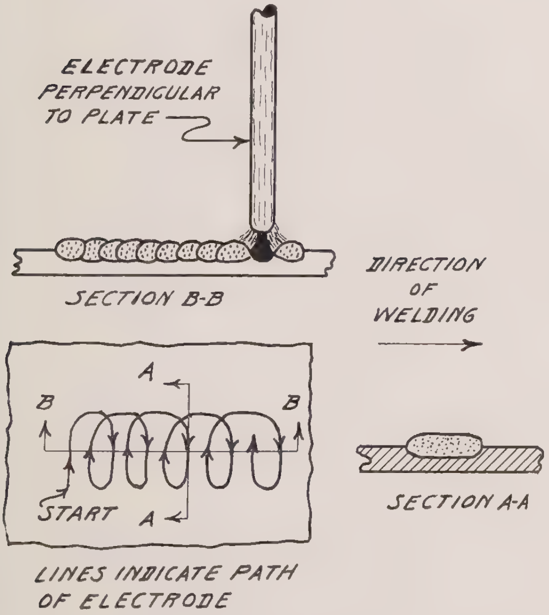

ELECTRODE PERPENDICULAR TO PLATE
SECTION B-B
DIRECTION OF WELDING
A
B
B
START
A
SECTION A-A
LINES INDICATE PATH OF ELECTRODE

Figure 20—This is a Sketch Showing a Lateral as Well as a Forward Movement of the Electrode Called Weaving, Which May be Used for Building up a Surface Either With Steel or With a Hard-Surfacing Metal.

The first exercise, namely, depositing a single bead, should also be practiced with the plate inclined at an angle of 45 degrees, as indicated in Figure 19 and in similar manner the parallel beads, and the three adjacent beads, the middle one on top of the first two, should be practiced at the 45 degree angle. These beads are also illustrated on the same plate in Figure 19.

So far the student has moved the electrode in a straight line only, and has not attempted to give it any lateral or sidewise movement. It is necessary to practice a good deal with the straight movement of the electrode with such padding exercises both in one direction, and transversely, that is, depositing one layer of beads in one direction and the next layer of beads at right angles over the top of the first layer. The student should use his judgment in this respect to enable him to gain as much practice as possible without using too much plate.

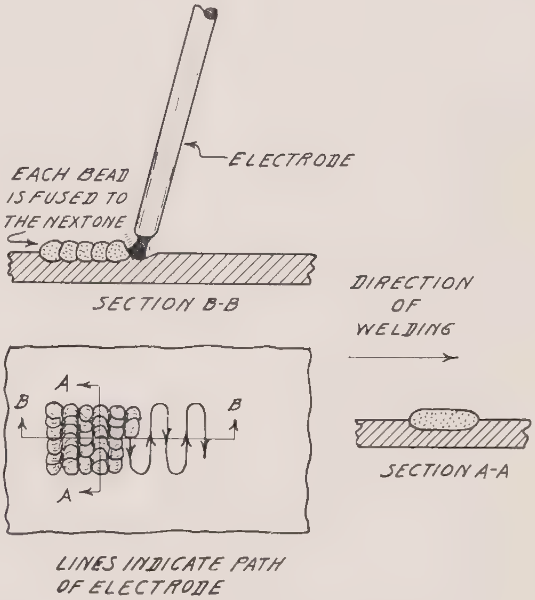

ELECTRODE
EACH BEAD IS FUSED TO THE NEXT ONE
SECTION B-B
DIRECTION OF WELDING
A
B
B
A
SECTION A-A
LINES INDICATE PATH OF ELECTRODE

Figure 21—This is Another Weaving or Spreading Movement of the Torch Used in Building a Surface Either for Reinforcement or Hardfacing. There Are Many Similar Movements, Each of Which May Have a Slightly Different Effect Depending Upon the Electrode in Use.

Spreading or Weaving

There are a number of different movements of the electrode which are used to widen or spread out the deposited bead. These are illustrated in Figures 20 through 24. Each motion has special significance with relation to the width and height of the deposited bead, the penetration, speed of welding, etc. These motions, however, are also dependent upon the type of electrode which is being used. Their action is to a great extent dependent upon the coating, if heavily coated electrodes are in use.

It is therefore very difficult to make specific recommendations as to what motion is to be used unless the electrode is known, as well as the preparation of the parts being welded.

The sketches are sufficient to permit the student to practice these various movements with electrodes which he has available upon both the horizontal and the inclined plate. Some of the movements are used extensively for building up worn surfaces with high carbon steel preparatory to overlaying them with hardfacing metal. Spreading or weaving is therefore a particularly important method of applying metal, and should be given considerable study and practice by the student before attempting to weld joints.

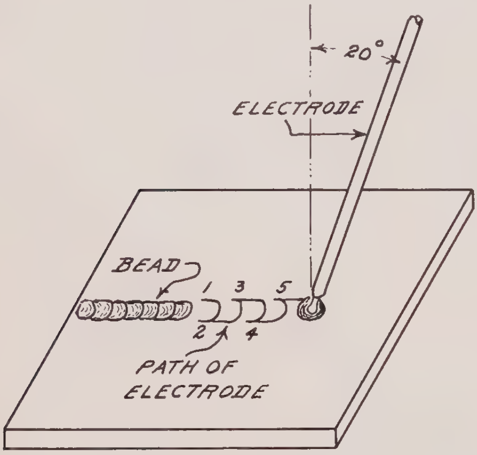


Figure 22—This is a Spreading Movement Which is Used in the Welding of Two Plates Which Have Not Been Bevelled. It Confines the Heat as Much as Possible to the Immediate Line of the Weld, and Yet Laps the Edges of Each Plate.

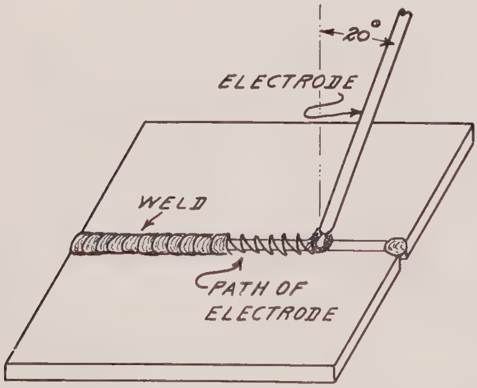


Figure 23—Another Spreading Movement Used to Increase the Width of the Bead and Often for Hardfacing. All of These Movements Will of Course Depend to a Considerable Extent Upon the Type of Electrode in Use.

After he has become proficient with these motions, and understands what they will accomplish with certain electrodes, he may proceed to weld various types of joints, such as joints which are butted together without bevelling, bevelled butt joints, lap joints, fillet welds in the corners of pieces of steel set at right angles, and the many other types of joints which are common to electric welding.

There are other movements which might be described, but it is necessary to limit this discussion of them because of lack of space.

Preparation of Steel Plates for Welding.

When steel plates are of greater thickness than $\frac{3}{16}$ in. they should be bevelled if butt welding is to be done. $\frac{3}{16}$ in. and even ¼ in. plates can be butted together and a weld made from each side without bevelling, but in most instances it is required that plates be bevelled to angles from 30 to 45 degrees on each plate making included angles of 60 to 90 degrees as shown in Figure 25. This bevelling may be done with the cutting torch or, if the thickness of the plate is light, the edge may be ground on a grinding wheel.

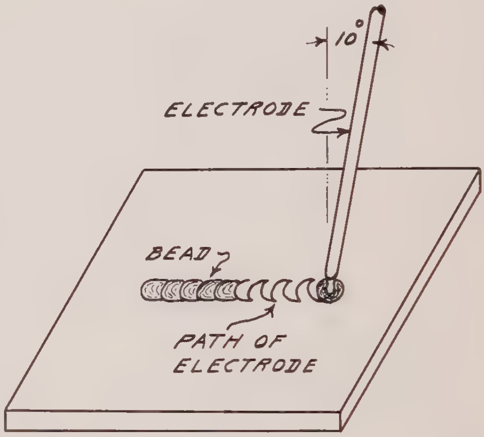


Figure 24—Another Spreading Movement Which May be Used if Desired. All Movements of the Torch Are a Matter of Preference of the Operator, and Are Dependent as Previously Stated, Upon the Electrode. The Manufacturer Usually Gives Recommendations for the Movements of Electrodes Which He Furnishes.

Heavier plates may be cut to great advantage with the cutting torch, and may be done with a hand oxy-acetylene torch without the use of a cutting machine if the welder is skilled in the use of the torch. All slag or oxide must be ground and cleaned away from these edges before welding takes place. Sketches 25 and 27 illustrate the angles of bevel in making butt joints, and these joints are more fully described under the next paragraph heading.

In electric welding many joints are made with fillet welds as shown in Figures 28 and 29. These welds require practically no preparation of the plate except to be sure that the surfaces have been well wire-brushed to clean them of dirt and grease. Cleanliness is one of the very important things in welding, and the cleaner the surface to be welded, the easier it will be to make a good weld. A wire brush similar to that shown in Figure 5 should be available at all times, and should be constantly used. When starting the arc in changing electrodes, it is often necessary to clean the weld deposit before again depositing metal. In using coated electrodes all slag must be removed before restarting the arc, when the weld has been discontinued for some reason or other. A wire brush will help in this cleaning.

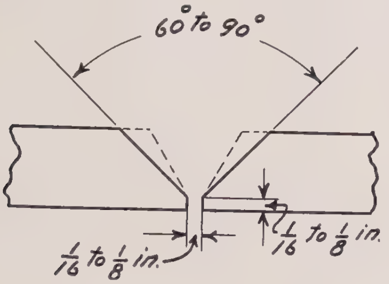

60° to 90°
$\frac{1}{16}$ to $\frac{1}{8}$ in.
$\frac{1}{16}$ to $\frac{1}{8}$ in.

Figure 25—Suitable Preparation of Plates for Welding is Exceedingly Important Especially if They Exceed $\frac{3}{16}$ in. Thickness. This Figure Shows the Angles at Which Plates Are Ordinarily Bevelled Leaving a Depth at the Root of the Vee of Not Less Than $\frac{1}{16}$ in. If the Vee is Bevelled to a Thinner Edge, the Arc Will Melt Through. This Bevel is Made Entirely From One Side for a Single Vee Weld.

It should also be noted in restarting coated electrodes that the coating will sometimes melt around the end of the electrode preventing the arc from being struck when it is brought in contact with the plate. The coating may be broken at the same time the arc is struck, if it is brought in contact with the plate sharply.

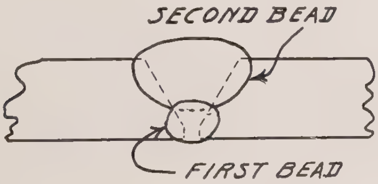


Figure 26—This Sketch Shows the Location of the First and the Second Bead Made in a Two-Bead Weld, Prepared as Indicated in Figure 25.

Welding Lighter Steel Sheets

In the welding of steel sheets thinner than $\frac{3}{16}$ in. it may be necessary to place a copper backing bar underneath the seam. This prevents the thinner metal from melting through, and provides a relatively heavier mass of metal underneath the seam which prevents the lighter sheet from becoming overheated. Backing bars made of copper will not fuse to the molten weld metal, and are very useful in many classes of work. It may be desirable to add to the backing bar, steel angles in certain instances laid on top of the sheets, and clamped to the backing bar as indicated in Figure 31. When it is necessary to prevent conductivity of the heat into the adjoining sheet, copper bars may be used instead of angles. These bars and plates represent a convenient method of keeping the seam straight and avoiding buckling.

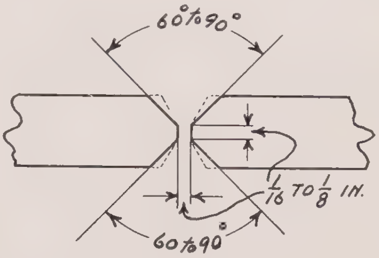


Figure 27—Sketch Illustrating the Preparation for a Double Vee Weld. In This Instance the Weld is Made From Both Sides of the Plate and is Used for Heavy Plates. Such Welds May be Made With a Number of Beads or Layers Deposited One Adjacent the Other, Until the Vee is Completely Filled.

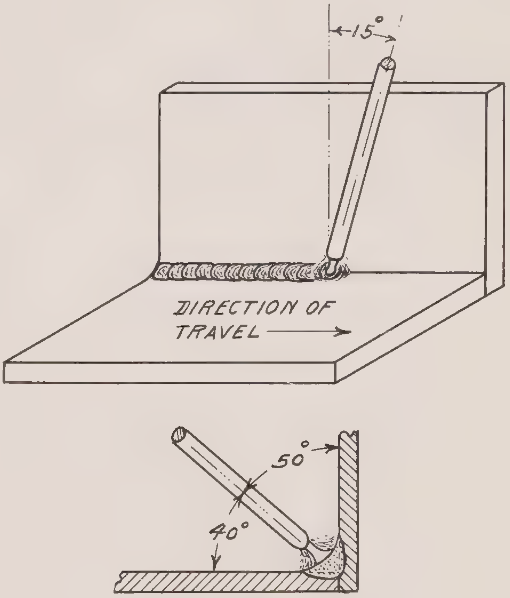


Figure 28—This Sketch Shows a Fillet Weld Made in the Corner of Two Plates Set Together at Right Angles. Fillet Welds Are Very Common in Electric Welding, and Are Used Extensively in Structural Steel and Other Welding Because no Preparation is Required, and When Properly Designed, Produce Strong Joints.

The deposited metal may be spread with a weaving movement of the electrode, and fused clear through the sheets from one side. This method is used extensively with stainless steel sheets using coated stainless steel electrodes.

Testing Welds

It is important in learning to weld to frequently break the joints made. If this is not done the student may be producing what he thinks is a good weld, while, as a matter of fact, the deposit may have little strength or ductility. It will be realized that in electric welding the operator has less control over the heat applied to the metal than he has in torch welding. With the torch he may draw the flame away from the seam, and graduate the heat to suit his convenience, but when he draws the electrode away the arc is broken, and welding ceases. It is therefore very essential in electric welding to make other conditions as nearly right as possible in every instance. In other words the seam must be properly cleaned and prepared. It must be held if necessary in suitable jigs with suitable backing bars underneath the seam, when required. The current in amperes or the "heat" must be right for the diameter of electrode in use, and the thickness of metal to which it is being applied. If these conditions are right, and the electrode is held steadily and moved forward with uniform speed, a good weld will result. If they are not right, poor welds will result, sometimes having little strength and being unfit for service.

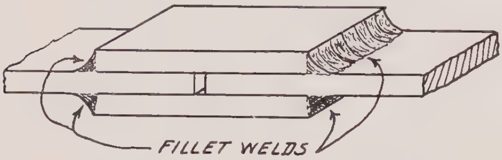


Figure 29—This is a Type of Joint Which Can be Readily Made by Fillet Welds Without Bevelling of the Parts. It is a Well-balanced, Strongly Reinforced Joint.

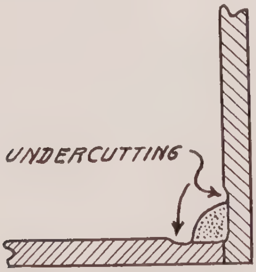


Figure 30—The Electrode Must be Held so That it Will Not Undercut the Plates Adjacent to the Deposited Metal. There Are a Number of Different Causes of Undercutting, and it Must Not be Permitted as the Reduced Section of the Plate Causes a Weak Area Adjacent to the Weld.

It is therefore essential that the welder determine what kind of welds he is making, and he can do this very easily by making certain tests which have been used for qualifying welders for structural steel work, recently described in publications of the American Welding Society.

Testing the first joint, A, illustrated in Figure 32, requires a tensile testing machine or a machine for pulling the bars apart. The average student has not the equipment to accomplish this work, but he should know what the requirements are, and how the work is done. This joint consists of two plates set together with a plate under and one over the joint. The first two plates are set ½ in. apart, and tack-welded on the edges so that they are in good alignment, and in such manner that the tacks may be chipped off. Four $\frac{5}{16}$ in. fillet welds are made between the reinforcing plates, and the main plates, as indicated at A in Figure 32. These fillet welds are afterward machined to ¼ in. fillets. When this is done, every welder is on an equal footing because the weld which he has made has the same cross section as the welds made by others. Penetration of the weld is of great importance, and when the fillets are thus machined off to equality, penetration is given even more emphasis. The specimens are then placed in a tensile testing machine which grips the ends of the bars and pulls until the welds give way. The passing requirement upon such work is 9,600 pounds per linear inch of weld, which is equivalent to 54,000 pounds per square inch of deposited metal.

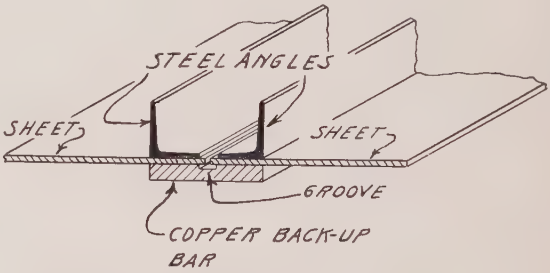


Figure 31—Sketch Showing a Copper Backing Bar and Two Steel Angles Used as a Jig for the Welding of Lighter Sheets. These Angles May be Clamped to the Backing Bar With C-clamps if Desired. This Will Prevent Overheating of the Lighter Sheets, and Keep the Sheets From Buckling.

At B in Figure 32 a simple fillet weld is shown between two plates, one set at right angles to the other. This weld is placed as indicated upon an anvil, and broken with a sledge. Careful examination of the broken cross section of the weld will show depth of penetration, fineness of grain, absence or presence of blow holes, and will give a fair idea of the strength of such a joint. If the welder has a pocket magnifying glass he can determine even more about the grain size, the presence of slag and other non-metallic inclusions, etc., within the weld deposit. This test can be made without special equipment.

Too much emphasis cannot be given to testing the welds made by the student as he progresses in his knowledge and skill in welding. He should break practically every weld which he makes by some means, either as shown in Figures 10 and 11, or by breaking the weld with a sledge as described. Constant breaking of the joints which he makes will quickly show the student whether he is proceeding correctly or whether he has fallen into some errors which are producing unsound welds.

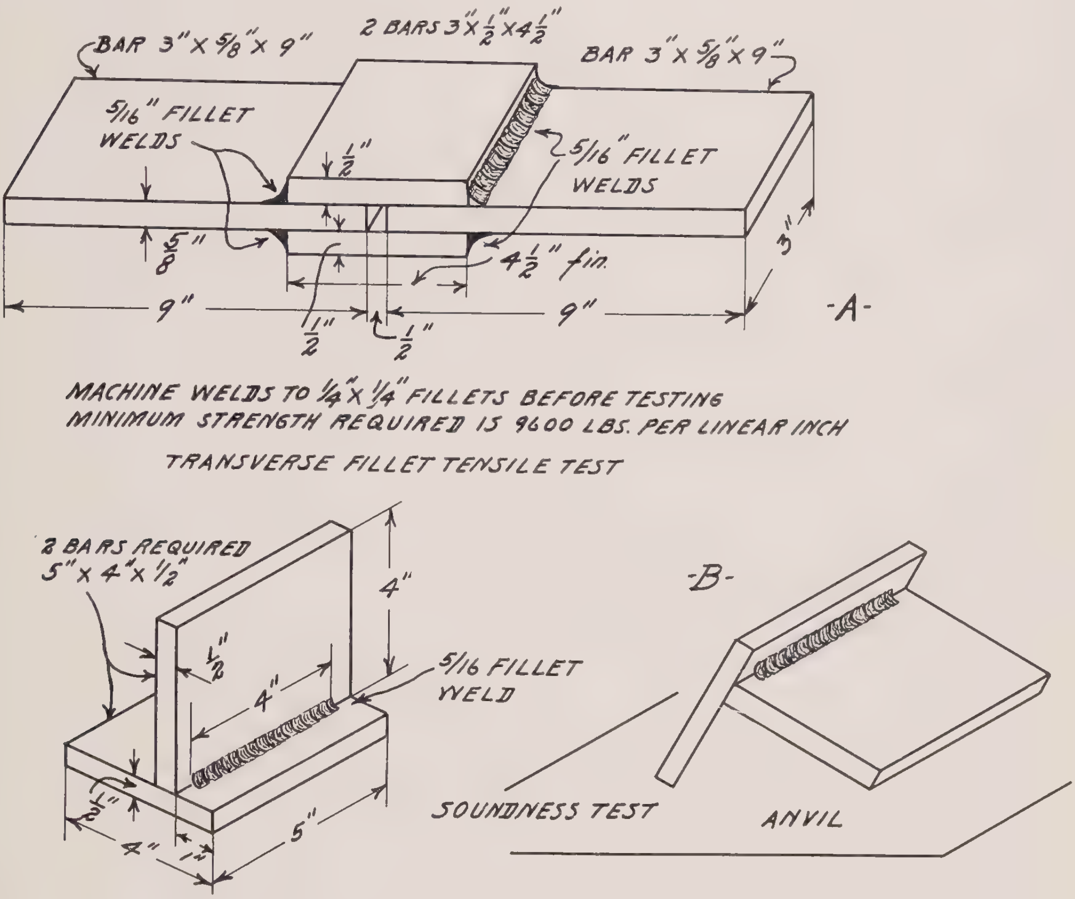

2 BARS 3"x½"x4½"
BAR 3"x⅝"x9"
BAR 3"x⅝"x9"
5/16" FILLET WELDS
5/16" FILLET WELDS
½"
⅝"
3"
4½" fin.
9"
9"
½"
½"
-A-
MACHINE WELDS TO ¼"x¼" FILLETS BEFORE TESTING
MINIMUM STRENGTH REQUIRED IS 9600 LBS. PER LINEAR INCH
TRANSVERSE FILLET TENSILE TEST
2 BARS REQUIRED 5"x4"x½"
4"
½"
4"
5/16 FILLET WELD
½"
4"
½
5"
-B-
SOUNDNESS TEST
ANVIL

Figure 32—Sketches Showing Qualification Tests for Welders Used by Some Companies.

Vertical and Overhead Welding

Vertical and overhead welding have been left to the last of this discussion as the welder should become proficient in horizontal welding before he attempts welding in other positions. In Figure 19 practice was indicated upon a plate leaning at 45 degrees, and it was suggested in the caption that the plate could be tipped to greater angles as the student gained in skill. Vertical welds should be practiced starting from the bottom and carrying the weld upward as well as starting from the top and carrying the weld downward. Horizontal beads should also be run on a vertical plate. Such welding requires skill, and the electrode used must be one especially adapted to the purpose. Manufacturers usually state whether their electrodes are suitable only for horizontal work, or whether they can be used in all positions. The coating has a great deal of bearing on this subject, and it is essential that a suitable electrode be used if the work is to be done correctly.

Overhead welding requires even more skill, and one excellent method of acquiring this skill is to place the practice plates at continually increasing angles to the vertical, until they are completely overhead, and the welder is working under them. Smaller electrodes are ordinarily used for overhead welding, and a slightly closer arc because the principle of overhead welding is largely one of surface tension, that is, forcing a drop of metal to cling to the inverted steel plate until it solidifies, and making this a continuous process. If the molten pool is allowed to become too great in size, it will fall, just as water will drop from the ceiling when the drop becomes too large. A small drop will cling, but when it is increased to a point where the surface tension is overcome, gravity causes the drop to fall. A little more "heat" or amperage will be necessary because of the shorter arc, and considerably more skill to deposit the metal from the electrode in a pool of just enough molten metal to cling, and yet not enough to cause drops to fall. Such skill can only be attained by constant practice.

Questions

1. With alternating current when the electrode is connected to the positive pole, is the arc hotter than if the electrode were connected to the negative pole?
2. Describe a satisfactory method for striking the arc on a steel plate.
3. What should be the proper length of arc when using a ⅛ in. bare steel electrode to make a bead on a ¼ in. steel plate?
4. What is a bead?
5. What should be done if the electrode sticks fast to the plate?
6. What is the crater?
7. In starting a new bead after the arc has been broken, what precautions should be taken to insure that the junction of the two welds will be sound?
8. What is weaving?
9. How should plates be prepared for a single vee butt weld?
10. Can plates be bevelled with the cutting torch?
11. Describe a double vee bevel.
12. What is shielded arc welding?
13. What is a backing bar?
14. Describe two good methods for testing welds.
15. Why does the molten metal adhere to the surface in overhead welding?

Lesson No. 3
Electric Welding of Cast Iron

CAST iron is a very different metal from steel. It has between one-third and one-fourth of the strength of steel. It will not bend, and will break if struck a sharp blow with a sledge. The shrinkage of cast iron as it cools from the molten temperature to ordinary room temperateure is less than the shrinkage of steel. It has a lower melting point than steel, this point being approximately 2,300 degrees F., whereas steel melts at about 2,750 degrees F., depending upon the carbon content. Cast iron is normally soft and easily machined. It is called gray iron because of the gray appearance of the surface of a piece broken from the casting. It must not be confused with white iron, or chilled iron, as this has a white surface when fractured, and is very hard and brittle. Cast iron must be very slowly cooled from the molten state in order to keep it soft. Quick cooling is likely to make it hard, and in complicated castings, unless great care is taken, quick cooling may result in cracking a casting.

When steel electrodes are used to weld cast iron, the molten steel of the deposit may absorb considerable of the carbon in the cast iron, making it essentially high carbon steel. There is also likely to be some carbon and other elements burned out of the cast iron, and with the quick cooling which occurs when arc welding this combination is likely to produce white iron, which is hard and brittle. For these reasons it will be appreciated that the electric welding of cast iron requires great care and skill, but it can be accomplished to advantage on many types of work which it is not desirable to preheat.

Electric Welding of Cylinder Blocks

The first example which will be described is the electric welding of a cylinder block. It quite frequently happens that an automobile is brought to a repair shop with the water jacket cracked. It is desirable to repair this crack without dismantling and removing the block from the chassis, and this can be done providing the work is accomplished generally in the following manner.

The crack should be veed out either by chipping or grinding to a very shallow vee. A vee such as that indicated in Figure 33 is the wrong one to use for electric welding. In Figure 34 a shallow vee or groove in a crack is shown, and this practice is much better.

Thorough cleaning with a wire brush is essential to remove all dirt, grease, and rust which may have accumulated in the crack. Often it is good practice to drill a small hole at each end of the crack before beginning to weld. This may assist in preventing the crack from extending when the heat of the arc is first applied.

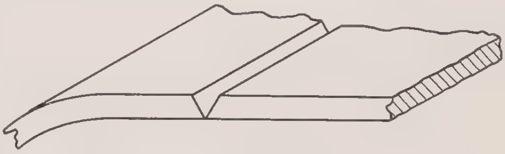


Figure 33—This Sketch Shows a Groove or Bevel Along the Crack Which Extends Clear Through the Casting Leaving Only a Thin Edge at the Bottom of the Vee. This is Not the Type of Vee Which Should be Made for the Electric Welding of Cylinder Blocks.

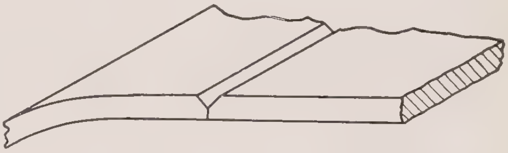


Figure 34—This Shallow Vee Which Extends Only Part Way Through the Casting, Leaving Considerable Metal at the Bottom of the Vee is Much Better Practice Than the Deep Vee Shown in Figure 33.

The use of special electrodes is recommended for such work. There are a large number of these electrodes, some of them being made of pure nickel, some being fabricated with a copper core and nickel or steel shell. Some are made of Monel metal, which is a copper-nickel alloy. It is also possible to use phosphor bronze electrodes, which are made of an alloy of copper, tin, and phosphorus. Most of these electrodes are coated, and the nature of the coating has considerable bearing upon their use.

If the electrode is used with a deep groove such as shown in Figure 33 the thin edges at the bottom of the vee will be melted, and flow together which is likely to cause subsequent cracking. If, on the other hand, only a shallow groove is used as shown in Figure 34, the metal from the electrode will melt into the shallow groove to better advantage without fusing the cast iron together. A reinforcing bead may then be made which will give greater strength to such a weld. Penetration in a job of this kind is not necessary, and is likely to cause trouble. The object is to keep the casting as cool as possible, welding only a very short length of the crack at a time, and allowing it to cool before welding again. The current must be low, and the electrode small, usually a ⅛ in. electrode. A current of from 18 to 20 volts and about 70 to 100 amperes is suitable for such work. The amperage should be just as low as possible to maintain the arc in good control. Peening the weld while hot will assist in reducing strains, but this must be done with great care. On direct current machines the current is usually reversed, that is the electrode is positive, and the casting negative. With alternating current machines of course either pole may be connected to the electrode holder.

When the short section not more than ½ in. in length of weld has been made, another section at the other end of the crack should be made, then one in the middle, alternating in this manner and allowing each section to cool before proceeding to the next. The principal thought which must be kept in mind during this work is not to overheat the casting.

Many more complicated cracks than the one in the water jacket can be accomplished in cast iron cylinder blocks, providing the welder has sufficient skill, obtains the right electrode, and uses a very low heat, welding intermittently as suggested. This same method may be used for the welding of cracks in cast iron boiler sections, and similar work, where the cast iron wall is relatively thin, and the casting is of a complicated shape.

Use of Steel Studs

When, however, a crack occurs in a heavy engine bed where the weld must be made in position, and the machine cannot be dismantled, the procedure is an entirely different one. In such instances, the wall of the casting is much heavier and the weld must be made so that it will have fully as much or more strength as the cast iron itself. In such instances the break is chipped out to a vee or a U-shaped groove, and ¼ in. to ⅜ in. diameter holes are drilled at intervals in the surfaces of the vee, which are subsequently tapped. Into these tapped holes steel studs are screwed so that they project from $\frac{3}{16}$ in. to ¼ in. above the cast iron surface. There are some types of studs which may be obtained having a tapered, threaded end which may be driven into a drilled hole thus eliminating the trouble of tapping. A coated steel electrode may be used, and a weld is made around the studs, fusing the deposit both to the stud and the cast iron until a surface of steel is built up between the studs. The weld may then be readily completed by depositing adjacent beads until the section is completely filled as shown in Figure 35. In spacing the holes for these studs, it is customary to make the area of the studs about 35 per cent of the total area to be welded. The steel is, of course, stronger than the cast iron, and hence less of it is required to give similar strength. When this is done, reliance for strength is placed mainly upon the studs, and not upon the bond between the cast iron and the steel.

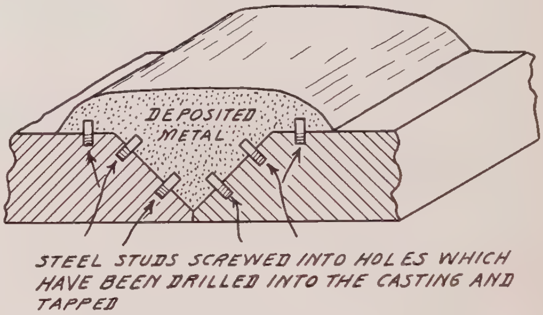

DEPOSITED METAL
STEEL STUDS SCREWED INTO HOLES WHICH HAVE BEEN DRILLED INTO THE CASTING AND TAPPED

Figure 35—Sketch Showing Steel Studs Screwed into Holes Which Have Been Drilled into the Cast Iron and Threaded or Tapped. These Studs Are Spaced Approximately as Shown to Anchor the Weld Deposit Solidly to the Base Metal.

In accomplishing such work, it is necessary to retard the heat as much as possible to prevent the casting from becoming too hot. In such a job, however, due to the much greater size and weight of the casting, overheating will be of less importance than with the smaller castings previously described.

In welding with steel electrodes, the coating has a very definite action on the hardness of the cast iron, and the deposited weld metal. Some coatings consist of compounds which under the heat of the arc produce graphitic carbon in sufficient quantity to replace that burned away in the cast iron, thus preventing the formation of white iron, which is hard and brittle. Other compounds tend to unite with the excess carbon absorbed into the weld metal from the cast iron, and prevent the hard iron carbides from forming in the deposited metal. The use of steel electrodes for the welding of cast iron therefore becomes a function of the coating, and some electrodes will produce much better results than others. Careful selection is essential.

Such a weld will suffice where machining is not necessary, as is the case in many instances. It is rarely necessary in the repair of a bed plate or casting similar to that described to do more than make a well reinforced weld at the point where the casting has cracked. There are cases, however, where the casting must be machined after welding, and then the procedure should differ from that described.

Welds Made With Non-Ferrous Electrodes

The weld made with a steel electrode, as in Figure 35, is likely to have a hard edge where it joins the cast iron, and this edge or line will seriously interfere with any machine work to be subsequently accomplished. It is true that the surface might be ground, but this would not be the equivalent, nor would it have the accuracy of machine work.

Where it is necessary to machine the casting through the weld, an entirely different procedure is required. This may be accomplished as follows: Instead of using coated steel electrodes, those used in such instances are of the non-ferrous type, that is phospher bronze, Monel metal, etc. These alloys will not absorb carbon from the cast iron, and hence do not become hard. They adhere well to cast iron, and with as low a heat as possible can be used to build up a veed out section with the assurance that when the weld is completed, machining may be done across the junction between the weld metal and the cast iron. The work must proceed, however, with great deliberation to prevent overheating the cast iron, and consequently causing it to chill and change to white iron adjacent to the weld metal. This will not occur if welding is done slowly, and carefully.

Questions

1. Why is the cast iron along the joint between the weld metal and the casting likely to be hard?
2. Why is the steel weld metal along the same joint likely to be hard?
3. How does the coating on a steel electrode change these conditions?
4. Describe the use of steel studs.
5. How should these studs be spaced to give the same strength in the joint as in the casting?
6. Is the weld metal hard when a non-ferrous electrode is used?
7. When the word non-ferrous is applied to electrodes in connection with the electric welding of cast iron, what electrodes are ordinarily referred to?
8. What is the essential requirement in welding cast iron with the electric arc?

Lesson No. 4

Welding Miscellaneous Metals

Aluminum

ALUMINUM is a light white metal having a melting point of approximately 1215 degrees F., which is used in sheets of the commercial pure metal for many purposes, such as tanks of various kinds, kitchen utensils, utensils used in the manufacture of candy, and other foods, and for many other purposes. It is easily welded, but requires a considerable knack, partly because its melting point is low, and partly because it does not show color when heated.

Aluminum is also manufactured in the form of strong aluminum alloys used for many purposes where strength and lightness are essential requirements. It is often alloyed with small amounts of manganese, silicon, copper, magnesium, and other elements. Cast aluminum is usually an alloy of aluminum and copper, the copper being from 4 to 8 per cent. In wrought aluminum, copper and manganese are used together, or in conjunction with magnesium, or silicon depending upon the special alloy being produced. Usually these alloys are heat-treated by heating them to from 940 to 980 degrees F., and quenching them in cold water. Some of them are also aged for a day or more at temperatures of 285 to 320 degrees F. This treatment increases the stiffness and strength of these structural alloys to a very considerable extent. In welding any of the structural aluminum alloys this special heat treatment must be considered in order that welding may not produce a soft area at the weld having less strength than the remainder of the piece.

Metallic arc welding of aluminum is used upon certain classes of work, and there is less buckling or warping of the work when welding with the arc than with the torch. This is true because the arc is more concentrated, and the temperature of the sheet or shape is affected over a smaller area. The electrode used must be a special one, usually a flux coated 5 per cent silicon, 95 per cent aluminum electrode. This alloy is used because there is less shrinkage during solidification than with pure aluminum. It also melts at a slightly lower temperature, and has a wider melting range, that is, it remains molten or soft over a greater range of temperatures than the metal being welded. A diameter of ⅛ in. is used upon all thicknesses up to 3⁄16 in. providing the technique is changed for various thicknesses of metal. These electrodes are approximately 15 inches long, and are coated, leaving a bare end about 1 to 1½ inches for contact between the electrode and the holder.

The Aluminum Company of America gives a table of thicknesses of plate in inches, diameter of electrode, and the number of amperes required for the metallic arc welding of aluminum. It is important that these settings be closely adhered to.

Whether the electrode is used at the positive or negative ends of a direct current circuit depends upon the electrode and the work being done. It is necessary to try each polarity to see which operates best under the existing conditions. The flux coating is important, but is corrosive, and after a weld is made, the flux must be very carefully removed by chipping off the excess, and soaking the weld in a hot 5 per cent nitric acid solution for several minutes, and then rinsing carefully with hot water.

Table Giving Amperage Used for Various Plate Thicknesses and Electrode Diameters

Plate Thickness Inches	Electrode Diameter Inches	Amperes
0.064	⅛	45-55
0.081	⅛	55-65
0.102	⅛	65-75
0.125	⅛	75-85
5⁄32	⅛ or 5⁄32	85-100
3⁄16	5⁄32	100-125
¼	5⁄32 or 3⁄16	125-175
5⁄16	3⁄16	175-225
⅜	¼	225-300

A short arc is essential. It should never exceed ¼ inches, and is preferably from ⅛ to 3⁄16 in. in length. The arc is struck in the usual manner as a match is struck, and moved quickly to the point where welding is to begin.

It may be moved in either direction along the seam as the operator may desire, and should be held approximately perpendicular to the seam and plate. Sometimes the electrode is slanted not to exceed approximately 20 degrees from the vertical, but when this is done, the electrode should point toward the completed work, that is, away from the direction of travel. The electrode is ordinarily advanced in a straight line, and is not weaved. When heavy plate is being welded, the electrode may be moved backward and forward to produce the desired height of bead. The rate of movement along the seam must not be too fast or too slow. If too slow, holes will be burned in the plate, and if too fast, there will not be sufficient penetration. The operator must "feel" his way along the seam, and can only become skilled by much practice.

In welding light aluminum sheets, the edges are usually flanged at right angles to the sheet, and placed together. When the sheets are heavier, they are bevelled or veed in similar manner to steel plates. When welding light sheets it is often desirable to place the sheets in a jig and to have a copper back-up bar underneath the seam. The vee should not extend clear through the plate. It should have an included angle of 90 degrees, and should be bevelled only about half way through. Back-up bars are usually made of copper, and will prevent the molten sheet from falling through, which often happens if an attempt is made to weld thinner sheets without such backing. Sometimes a groove is cut in the backing bar which lies directly under the seam, and thus permits reinforcement of the seam on the underside.

Stainless Steel

Stainless steel is a name given to many alloys of steel, chromium, and nickel, and of steel and chromium alone, which is highly resistant to corrosion, and has a bright silvery appearance. It is used in the chemical, dairy, food, paper, oil, railroad, and other industries for the fabrication of vessels, containers, tubing, railway cars, and many other parts which require great strength, or are subject to corrosion from various causes. It is being used extensively for an increasing number of purposes, and is made in the form of plates, bars, sheets, tubing, strips, bolts, rivets, nuts, wire, etc., and can be formed or drawn into almost any required shape.

There are many alloys of steel, chromium and nickel, or steel and chromium alone, which are used in the industry, but the most common of these from the welder's point of view is 18-8 steel, that is, steel containing 18 per cent chromium, and 8 per cent nickel. This alloy, particularly in the low carbon groups, is readily welded, and subsequent heat treatment is not necessary to prevent later corrosion between the weld metal and the base metal.

Chromium steels are peculiarly affected by the presence of carbon in the metal, which is likely to separate during welding and collect at the grain boundaries of the metal. This causes what is known as intergranular corrosion, or a corrosion which takes place at the grain boundaries after welding is completed. Such corrosion can be avoided by subsequently heat treating the welded parts.

Heat treatment of many welded articles is expensive and difficult, and should be avoided wherever possible. In order to avoid the effects of carbon and eliminate heat treating, most stainless steel which is fabricated by welding is of the 18 chromium 8 nickel type, having a low carbon content. In many instances this content is as low as 0.07 per cent, in others slightly higher.

Stainless steel electrodes are generally made of the 18-8 alloy with a very low carbon content, and are further alloyed with titanium or columbium. Molybdenum is another element which is frequently alloyed with stainless steel. The following general description of the metallic arc welding of these steels refers particularly to the 18-8 group.

The preparation of the stainless steel sheets is generally similar to that of steel. Up to ⅛ in. no bevelling is necessary. With $\frac{3}{16}$ in. steel, if only one bead is to be deposited from one side, the edges should be bevelled to an included angle of 90 degrees, that is, 45 degrees on each sheet. $\frac{1}{16}$ in. should be left unbevelled at the bottom of the vee. When the steel is ¼ in. in thickness, two beads are usually required. In this instance bevelling is done from both sides to make a double vee weld, and $\frac{3}{32}$ in. of unbevelled plate left at the center.

Stainless steel has a coefficient of expansion about 60 per cent greater than ordinary steel, and this increased expansion must be allowed for in setting up a joint between two plates. The heat conductivity of 18-8 stainless steel is lower than that of carbon steel. This tends to keep the heat localized in the zone of welding. In welding sheets it is most satisfactory to use a suitable jig, which will clamp the edges in place, and a copper backing bar or strip in which a groove has been cut lying directly under the seam. If the sheets are clamped in such a jig slightly separated and welding done from the unpolished or rough side of the sheet, the molten puddle will settle into the groove, forming a reinforcement on the finished side, which may be later ground off or repolished.

When circular or other parts are welded, it is often desirable to tack-weld the seams about every two inches on the unpolished side of the sheet.

The electrode is a highly specialized alloy which is flux-coated with elements and compounds which will protect the metal during welding, and stabilize the arc. When molten stainless steel is permitted to contact the air, the iron and the nickel are not as seriously affected, but the chromium oxidizes very rapidly, and in welding, protection of the molten metal is essential. This is accomplished with the flux-coated rods, both by shielding the molten puddle with gases, and also by covering the solidified weld with slag. The slag may be easily removed afterwards with a suitable tool, but care must be taken to thoroughly clean each bead before a second bead is laid upon it.

With direct current machines reversed polarity is ordinarily used, that is, the electrode is made positive and the sheet or plate negative. In some cases, however, straight polarity may be desirable. With alternating current of course, polarity is not a factor.

The melting point of stainless steel is slightly lower than that of ordinary carbon steel, being given as 2640 degrees F., for the low carbon varieties, and, because of the lower heat conductivity, hence concentration of heat, the amperage should be kept as low as possible. As a comparison, if approximately 110-125 amperes were used with a ⅛ in. carbon steel electrode, and carbon steel sheets, then from 90-100 amperes would be used on a similar job with ⅛ in. 18-8 electrodes, and stainless steel sheets. Because stainless steel is quite fluid when molten, penetration will be greater than on carbon steel. Welding stainless steel with bare electrodes should not be attempted, since if this is done, the weld metal is likely to be porous and brittle.

Copper

Copper is a metal known to everyone. It has been in use for many centuries. Before discussing its fabrication by metallic arc welding, a few words should be said about some of its characteristics.

Copper, as it is ordinarily purchased in rod, plate, or sheet form, is what is known as electrolytic copper. It is called electrolytic because during the process of refinement from copper ore, a process is used which is similar to the electrolytic plating process, that is, the large slabs of copper which are received at the refinery are placed in a plating vat, and by the usual plating process deposited on a sheet forming a cathode. This separates the gold and silver in the copper, and produces very pure copper, but the cathodes are not in convenient shapes for commercial use, and are again melted up in a furnace and cast into the commercial forms of bars, billets, etc. During this second melting process all of the oxygen which can be readily eliminated is removed by stirring the copper with green wood poles. There remains a small amount of approximately 0.03 to 0.07 per cent of oxygen in the metal. This does not affect the copper from a commercial standpoint, but it does seriously affect its welding characteristics.

A much smaller heat of copper is further refined, as required, by the addition of silicon, phosphorus, and other deoxidizers to produce what is known as deoxidized copper, the welding characteristics of which are very different from those of electrolytic copper.

Deoxidized copper can be welded without the inclusion of cuprous oxide which causes weakness, brittleness, and porosity in electrolytic copper. Electrolytic copper may be satisfactorily welded by the long carbon arc process, but as this process is a highly specialized one, it will not be discussed here.

Copper melts at approximately 1981 degrees F., and is very fluid when molten. It has high heat conductivity, being between eight and nine times that of steel, and this makes it exceedingly difficult for most welders to weld copper much more than $\frac{1}{16}$ in. in thickness with the metallic arc. If ¼ in. copper plates are used, a $\frac{5}{32}$ in. diameter electrode and about 200 amperes, it is necessary to preheat the copper to a red heat before it can be welded. The thinner plates and sheets, however, may be welded, as for instance $\frac{1}{16}$ in. deoxidized copper sheet spaced about $\frac{1}{16}$ in. apart, using about ⅛ in. deoxidized copper electrodes, and approximately 175 amperes, without preheating. Good welds may be obtained in this manner. If vessels, tanks, containers, etc., which have been in the past fabricated of copper were made instead of sheets of weldable copper alloys, the fabrication of them by welding with the metallic arc would be greatly simplified. Such alloys can be obtained, and are discussed in detail in subsequent paragraphs.

Everdur

Everdur is an easily fabricated copper alloy which is used for tanks, tubing, containers, hot water boilers, structural shapes, such as the frames for the glass in store fronts, ornamental work, and many other purposes, where a strong corrosion resistant metal is required.

Everdur is an alloy of copper, silicon, and manganese, and contains approximately 1 per cent manganese and about 3 per cent silicon. Its melting point is 1866 degrees F., and it has approximately the strength of steel. The effect of the manganese and silicon upon the copper is to give the metal self-fluxing properties which make welding much easier.

Everdur electrodes may be obtained and are used with reversed polarity, that is, the electrode is positive, and the work negative. The preparation is generally the same as for steel, the plates being bevelled when $\frac{3}{16}$ in. in thickness and thicker. A copper back-up bar with a groove should be used under the seam. The electrodes will fuse readily and the metal will deposit in large drops requiring considerable skill to obtain good fusion. The heat of the arc should be confined as largely as possible to the area of the weld. A flux may be used if required, consisting of 90 per cent fused powdered borax, and 10 per cent sodium fluoride.

Beads more than ¼ in. in thickness should not be laid at a single pass. When more than one bead is deposited, each bead should be lightly peened, and cleaned before the next bead is laid. When the weld is completed, it should be lightly annealed with a torch. Everdur may also be welded with the carbon arc.

Monel Metal

Monel metal is an alloy of copper and nickel consisting of about 67 per cent to 70 per cent nickel, 2 per cent to 4 per cent iron and manganese, the remainder being copper. It has a melting point of approximately 2480 degrees F., and heat conductivity of approximately $\frac{1}{15}$ that of copper, or a little less than one-half that of steel. Its coefficient of expansion is about one-fifth less than that of copper, or slightly more than that of steel. It has a silvery white color, and is used for many purposes such as corrosion-resistant tanks, containers, counter tops in restaurants, bar tops, and for many other purposes where an easily fabricated, bright metal is required.

In welding Monel metal sheets, it is always desirable to use jigs where the sheet is supported by a copper back-up bar, and the sheets are held in place with either permanent or temporary contacting bars or angles.

The preparation of the sheets is generally the same as for steel, and consists of ordinary bevelling, but with lighter sheets, not requiring bevelling, it is good practice to flange them slightly before placing them in the jig.

The metal is readily welded with the metallic arc, using heavily flux-coated electrodes of the shielded arc type. The heavier coated electrodes have produced better results, greater strength, and ductility, and somewhat higher speeds than the lightly coated or bare electrodes. The diameter of the electrode should be approximately the thickness of the sheet up to $\frac{3}{16}$ in. For heavier plate a $\frac{3}{16}$ in. or ¼ in. electrode is ordinarily used. The electrode is normally held in a position approximately twenty degrees from the vertical in line with the seam, and pointing in the direction of the weld travel. When using direct current and the heavily coated electrodes, the electrode should be made positive and the work negative.

Amperage can be determined by trying the electrode on the work, and if it is found that the metal is not flowing smoothly, the amperage should be increased. If, on the other hand, the metal is too hot, or boiling, and a shower of sparks are being thrown off, the amperage is too great, and should be cut down. Amperage or "heat" is dependent upon the thickness of the sheet, the diameter of the electrode, the type of jig in use, and other factors, and the welder must use his own judgment.

A uniformly short arc should be used, and a slow slight weave across the seam is usually recommended to produce uniform penetration. The flux coating should be removed after welding with ordinary tools for this purpose. If any slight amount of flux remains, it is not usually corrosive to the metal.

Brass and Bronze

Brass is an alloy of copper and zinc in varying proportions. What is commonly called brass may contain from 63 per cent to 75 per cent copper and from 37 per cent to 25 per cent zinc. The melting temperatures of these various proportions range from 1670 degrees F., to 1790 degrees F. Brass has a heat conductivity which is greater than that of steel, but less than that of copper.

Tobin bronze is an alloy of approximately 60 per cent copper, 1 per cent tin, and 39 per cent zinc, which is commonly used as a welding rod for bronze welding of cast iron with the torch, and for torch welding of the various brasses and bronzes. The zinc content of these alloys, however, boils under the heat of the arc, with the result that if such alloys are used as electrodes, the welds will be porous and lack strength and ductility. It is therefore not good practice to attempt to use these alloys in connection with the metallic arc.

On the other hand, a bronze which is used extensively for metallic arc welding is what is generally called phosphor bronze. This is an alloy of copper, phosphorus and tin. The phosphorus is used mainly as a deoxidizer, and is largely volatilized in the manufacture of the electrode. In some grades of phosphor bronze there is approximately 95 per cent copper, 5 per cent tin, and in other grades 90 per cent copper, and 10 per cent tin. The amount of phosphorus is not usually specified, because of its small quantity.

This bronze containing no zinc is used in metallic arc welding for many purposes. The melting point of the 5 per cent tin phosphor bronze is approximately 1922 degrees F., and the 10 per cent tin phosphor bronze 1832 degrees F. It is used both coated and uncoated for the welding of cast iron, and many of the bronze alloys.

When phosphor bronze is used upon cast iron the polarity with direct current is usually straight, that is, the electrode is negative and the work positive. This condition may be changed in the use of certain types of coated electrodes. As a rule, however, with phosphor bronze electrodes, the electrodes are used on the positive side of the circuit. In using prosphor bronze electrodes the heat should be kept as low as possible using only enough amperage to secure good fusion with the base metal, if bronze or copper, and a good bond with the base metal, if welding cast iron.

Nickel- and Stainless-Clad Steels

Tanks and other containers are being made to a continually greater extent which have a thin veneer of nickel or stainless steel on the inside of the steel plates forming the tank. This layer or veneer is thoroughly bonded to the steel during the rolling of the plates. Welding is easily accomplished, but care must be taken to see that the veneer is not broken along the seam.

In other words, if the veneer is nickel, nickel electrodes should be used on the veneered side of the steel to make a small weld. On the opposite side of the seam the weld is made with steel electrodes. The preparation is similar to that of a double bevel weld except that the bevel from the nickel side is much shallower than that on the steel side. The steel side weld is usually made first, and when completed the small vee on the nickel side is chipped clean of slag or oxide which may penetrate into this vee during the steel welding. When this has been accomplished, the nickel weld is made, fusing into the steel of the sheets and also the steel weld metal.

Flux-coated nickel electrodes should be used with reversed polarity when using direct current, and a short arc. If the plate thickness is from $\frac{3}{16}$-$\frac{1}{4}$ in. a $\frac{1}{8}$ in. diameter electrode should be used with from 90-150 amperes. The same general practice would be used with stainless-clad steel, or any other clad steel.

In the case of stainless-clad steel, the weld would be prepared in generally similar manner to that described above, the steel weld being made first, using a steel electrode. The stainless steel weld from the stainless side would be made after the vee was carefully cleaned and chipped, using stainless steel electrodes, and the same practice as was given for the welding of stainless steel.

Hardfacing

Hardfacing or hard surfacing is the welding of a layer of hard metal on a softer metal, usually steel. This increases the wear-resistance of the surface, and thus the life of the article is considerably lengthened. In some districts a large part of the business of a welding shop will be in hardfacing, depending of course upon the location.

In farming districts there is the hardfacing of plow shares, cultivation tools, and other agricultural implements. In quarry districts there is the hardfacing of manganese steel parts, and other parts which are subject to wear. On construction work there is the hardfacing of steam shovel dipper teeth, dredge dipper teeth, cutting heads in suction dredges, and other various parts about such equipment which wear out on account of abrasion. In cement mills, brick plants, coal mines, and other manufacturing industries, conveyor parts, bucket lips, and an infinite number of parts of machinery subject to wear can be hardfaced to materially increase the life, and thus save much money in maintenance.

A large proportion of hardfacing is done with the metallic arc. In manganese steel castings almost all building up of worn parts, and subsequent welding of a layer of hard metal over the built-up part is done with the metallic arc, because such welding can be done without overheating the manganese steel casting, and thus changing its characteristics.

To accomplish this work there are many hardfacing electrodes upon the market, consisting of an iron base alloyed with such metals as chromium, manganese, borium, carbon, nickel, and other metals which produce or increase the hard iron carbides and other hard compounds in the metal. These alloys are far too numerous to specify in detail here, but a few remarks should be made about the characteristics which govern their selection.

In the first place a hardfacing metal must be suitable for the work which it has to do. If the part is subject to the wear of sharp sand or some other gritty abrasive, it is necessary to select a metal which has great hardness. Metals which have great hardness are usually brittle. Therefore, if the class of work is one involving shock, such as the digging of rock, the hardfacing metal must be tough as well as hard. The very hard, brittle metal would chip or spall off the part under these conditions, while the tougher metal, being less hard, and yet having greater toughness and strength, would stand up under such service.

The various hard surfacing electrodes are very carefully described, the hardness given, and their uses recommended by the manufacturers of them. The welder must become familiar with these electrodes and those classes of work for which they are recommended. Usually the manufacturer also recommends the amount of current required for electric welding, and the movement or weaving most suitable for each electrode. Such data cannot be given in a general treatise of this nature, and can only be specified for each particular electrode.

Many of the new hardfacing electrodes are coated, and the coating definitely affects the technique of welding. Hence the necessity for careful study by the welder in this connection.

The foregoing remarks have referred particularly to the iron base electrodes, that is, those containing a considererable percentage of iron. There are other alloys upon the market which are used for hardfacing, which do not contain iron. These are alloys of cobalt, chromium, tungsten, and other metals. As a rule, however, these alloys are applied with the oxy-acetylene torch, rather than with the arc, although in some instances the arc may be used.

It is necessary for the welder to become familiar with the several hardness scales generally used so that when hardness is given in terms of any one of these scales, he will have a general idea whether the electrode is an extremely hard one, or has a medium degree of hardness. It is also well to have fixed in mind the relation of these degrees of hardness to that of high carbon steel, heat-treated, as in a tool.

There is another class of hardfacing material known as tungsten carbide. This hard alloy is almost as hard as the diamond, and is used for facing cutting edges such as oil well drilling tools, and other cutting tools of similar nature, which require the greatest degree of hardness, and will at the same time warrant the expense of application. Tungsten carbide is applied with the metallic arc in many instances, but the electrodes must be suitable for the application. Such suitability and the methods of application are specified in detail by the electrode manufacturer.

Manganese Steel

Manganese steel castings and other parts are made of what is generally known as Hadfield steel. It consists of approximately 10-14 per cent manganese, 1.00-1.40 per cent carbon, 0.30-1.00 per cent silicon, the balance being steel. It is very easy for the welder to tell whether a piece of steel is manganese steel or not, by using a magnet. Carbon steel is magnetic, that is, it will attract a magnet; manganese steel is not.

The use of arc welding in building up worn manganese steel parts is extensive wherever crushing, quarrying, excavating, or other similar machinery is in use. Special electrodes are used containing nickel. Manganese steel has a characteristic which must be recognized when any welding is done. It is hard and brittle, when first cast, but by heating it up to approximately 1940 degrees F., and quenching it in water it becomes much softer and very tough.

It has the quality of work-hardening, that is, as it is pounded, it becomes harder and tougher. If, however, heat is applied, as with the arc, and the metal is brought to the melting point, and allowed to solidify, it loses these hard tough qualities, and becomes brittle again. When nickel is added to electrodes or to small castings, the welding characteristics are greatly improved, and it may be welded without such difficulties. It is of course too expensive to make large castings of nickel manganese steel, and for this reason only smaller ones, which are to be welded, and electrodes, are made with small percentages of nickel.

Special bars, repointer teeth, and various other parts which are used to build up or reinforce worn crusher jaws, dipper teeth, etc., are made of nickel manganese steel, and these may be readily welded with nickel manganese steel electrodes. When working upon larger castings, however, which do not contain nickel, it is necessary to be very careful not to heat the casting any hotter than can be avoided. This is done by welding only a small area at one time, and then skipping to a point distant from the first point, and welding a small area, returning to a point near the first point welded only after the casting has cooled considerably. By this alternate method a large area of a casting may be built up without heating the casting appreciably, except at the immediate point where welding is being done. The nickel content of the rod assists in preventing brittleness in the casting. The old practice of quenching the casting with water is no longer desirable when using nickel manganese steel. Peening with a light hammer is usually good practice, but quenching should be avoided in most instances.

Normally, reverse polarity is recommended when using direct current, that is, the electrode is made positive and the work negative. This recommendation is given for either bare or coated electrodes. When alternating current is used, it is usually necessary to use a coated electrode. The welding current should be just as low as possible to produce satisfactory penetration and to maintain the arc under good control.

It is possible to build up carbon steel with nickel manganese steel electrodes, and when this is done the deposit upon the carbon steel has the tough, abrasion-resistant characteristics of manganese steel.

Questions

1. What is the melting point of aluminum?
2. Why is a 5 per cent silicon aluminum electrode used?
3. What alloy of stainless steel is most widely used when fabrication is required?
4. Is carbon an important element in stainless steel?

5. Why is it necessary to use stainless steel electrodes which are very low in carbon?
6. What other elements besides nickel and chromium are alloyed with stainless steel electrodes?
7. What is deoxidized copper?
8. Has copper greater or less heat conductivity than steel?
9. What is the melting point of Everdur?
10. What metals does Everdur consist of?
11. What is Monel metal?
12. What metals does Monel metal consist of?
13. Is the heat conductivity of Monel metal high or low?
14. What is Tobin bronze?
15. Should brass or Tobin bronze electrodes be used with the arc?
16. What would happen if such metals were used with the arc?
17. What is a clad steel?
18. If a part to be hardfaced were subject to abrasion by sharp sand, would you use a hard or a tough metal?
19. Why is the arc used so much in building up manganese steel parts with manganese steel electrodes?

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